

Memory for time: the use of temporal codes versus
contextual information

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ABSTRACT

Time-code theories of temporal memory argue that memories are tagged with dedicated temporal information which assist temporal judgments (e.g., G. D. A. Brown & Chater, 2001). Though this account is studied mainly with short-term memory paradigms, some models propose such information is available across time periods. This thesis investigates whether intrinsic time information may facilitate temporal judgments at longer spans, using long-term memory (LTM) paradigms and investigations of remote memory. An alternative proposal is considered where we may rely on contextual associations to make these judgments. In LTM, judgments of recency on studied items were not more accurate for recently seen items, contrary to the time-code hypothesis. Neither do temporal ratios of the distance between items and the present relate to accuracy scores. Instead, the presence of a robust primacy effect, preserved when rehearsal is minimised, supports a reconstructive approach where the beginning of a list acts as a temporal landmark. This position is supported by experiments which establish that this landmark effect can be reproduced at other list positions, for events that follow that landmark, and that a corresponding recency effect is not evoked by greater expectation for the end of the list. Investigation of remote memory revealed that for a set of public events dating was no more accurate for individuals who had lived through them, and for those cases dating accuracy was unrelated to measures of primary memory, such as memorability or content knowledge, but did relate to where the event could be localised within a personal life period. A case series investigation of neurological patients suggests an interrelatedness between measures of order memory and forms of context memory, and presents cases where order memory is impaired despite a normal ability to estimate time durations. These studies are broadly supportive of a contextual account of temporal memory.

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1. GENERAL INTRODUCTION

“We speak of this time and that time, and these times and those times: ‘How long ago since he said this?’ ‘How long ago since I saw that?’ ‘This syllable is twice as long as that single short syllable.’ These words we say and hear, and we are understood and understand. They are quite commonplace and ordinary, and still the meaning of these same things lies deeply hid and its discovery is still to come.” (Augustine, *Confessions*, Ch. XXII)

Time, and our memory for the time of things, is an apparently seamless quality of human experience. We have a sense of an ordered personal history that under normal circumstances does not appear to require any special effort to maintain. “Time remains in the background” (Friedman, 1990, pg 1). However, attributing temporal qualities to our stored or retrieved memories requires computational work, particularly if those qualities are to have correspondence to the world. Time in memory is a problem; a problem for “the poet, philosopher and psychologist...biologist....physicist” (Ornstein, 1969, pg 15). I address this issue from the vantage of the cognitive psychologist, and this thesis relies upon the preceding scientific literature, drawn chiefly from cognitive psychology but supplemented by neuropsychological research, together with new findings reported here.

This thesis addresses the following issues.

- Is the way in which time is handled by memory scale-invariant — does it apply across all time-scales?
- Is temporal memory reliant on a dedicated system dependent upon time?
- Is the dimension of time navigable in memory by the use of a heuristic, similar in nature to navigating space via landmarks?
- Is temporal memory a particular instance of context memory, or is it separable and distinct?

Section 1.1 of the present chapter examines the issue of temporal memory and temporality in the human system more generally. It reviews the evidence for biological timing mechanisms in the brain (Section 1.1.2) and addresses both the attractions and dangers of using this as a basis for explaining temporal memory (Sections 1.1.3–1.1.4). Section 1.2 reviews the various models used to account for temporal memory, as well as the paradigms used to investigate them.

On the basis of the amounted evidence, Section 1.3 challenges the idea that temporality in LTM flows naturally from the existence of short-term interval timing mechanisms. Finally, Section 1.4 lays out the aims of the experimental work presented in the chapters that follow.

1.1 *Time and memory*

Memory is a system of storing the past, and so cheating time. It allows our cognitive systems to seize information that is currently unavailable in the environment, and gain command of our surroundings at a pace that outstrips genetic honing and conditional learning. It does this by providing input to mental models of the world that is not supplied by the current environment; who is a threat, and why; where food may be stored; how a predator may be defeated. Any entity wholly dependent on the information offered by the current environment could produce only highly-bounded behaviours; memory loosens these constraints by offering information from previous environments: it “frees us from the tyranny of perception, allowing behaviour to be guided by the past as well as the present” (Kihlstrom, 2002). Suddendorf and Corballis (1997) argue that our ability to engage with our past and future uniquely characterises the human mind; it is no exaggeration that this ability to step outside of the present underpins our functional capacities and our identities. I shall initially take some space to draw out the ways in which memory traps the past, then focus upon the one sense that this thesis shall pursue.

1.1.1 *The temporal quality of memory*

The capture of the past to inform the present is a feature of every types of memory examined in modern psychology. The procedural knowledge of how to uncork a bottle is the information derived from an accumulation of past instances of similar activities, as is the semantic knowledge about the qualities of the wine in question. In both cases, the memory component of the situation is precisely the knowledge which can be considered beyond that directly afforded by the environment

— a priori or prior knowledge. The episodic memory system has an even more intimate relationship to time: one that has lead Wheeler, Stuss, and Tulving (1997) to describe it as mental time travel.

Consider the “I Spilled Wine On Professor Plum’s Easel Debacle”, or ISWOPPED. This incident, if it has occurred, has occurred in the past, and so may contribute to semantic and procedural knowledge. What distinguishes this event is that beyond having a generic past, allowing it to contribute to prior knowledge, it also provides a specific past. The information from the event is retained, not merely as information contributing to knowledge banks, but as information about the event itself, which Tulving puts as “remembering past happenings” (Wheeler et al., 1997, pg 331). Even if ISWOPPED had produced no information that could be usefully generalised, or used for building skills, the event itself could be laid down in memory, not as knowledge extracted from the event but information representing the event for future referral.

This is a particularly useful ability: an event may contain much information which may not appear useful or meaningful at the time, but might be extremely pertinent were one able to revisit it. Episodic remembering may serve a purpose in extracting information post-hoc, but there are good reasons for thinking its contribution goes much further than this. Kihlstrom (2002) argues it is “the ability to represent and reflect on the past” that offers “the basis for human freedom and dignity”.

In this cheating of time, this preservation of what was, there is a danger of losing entirely the temporal component of memory. This could happen in one of two ways. Firstly is the danger that a memory, by dint of being an accurate representation of an event, contains no revelation that it is an event that is of the past. This is an argument made by Martin (2001), that re-presentation of an event risks creating the illusion of a fresh experience of the event, and what is needed is a metarepresentational aspect, a qualia or subjective experience of the event, that fences it off from new experience and demarcates it as remembering. This is, he argues, the function performed by Tulving’s “autonoetic consciousness” (Wheeler et al., 1997) that allows memories to have a pastness about them.

The second danger is that we might lose *where* in the past an event occurred, that is, at what chronological point in time. This is the central issue addressed by this thesis, and from hereon any reference to temporal memory refers to this issue — the chronological point in time at which an event occurred. One reason why this would be dangerous is that it would interfere with our ability to have a coherent autobiographical memory. This is important in three ways: its *Directive*

Function, guiding our thought and behavior; its *Self Function*, enabling us to construct and retain a sense of identity, formed from our previous experiences and their causative effects on one another; and its *Social Function*, allowing us to maintain social cohesion through common narratives (Bluck, Alea, Habermas, & Rubin, 2005). A directive function is also evident for memory in the shorter term, such as judging the causality of two proximal events (eating a particular fruit and becoming ill) or remembering the status of food hidden in a cache (Clayton, Bussey, & Dickinson, 2003).

Because of these functional consequences, the mind is designed to give us some sense of the temporal context of memories. Episodic memory, according to Tulving (1972), is a system that “stores information about temporally dated episodes or events, and temporal-spatial relations among these events” (pg 385). It is considered to contain information on the *what?* *when?* and *where?* of events (Aggleton & Pearce, 2001). This *when?* aspect provides us with those uses described above. However, in the words of Friedman, “it is by no means clear what information we use to figure the chronology. Is the mind a kind of archives, ordered or indexed by date? Do we actually use the fading of memories to tell what events belong to yesterday and what to our distant childhood?” (1990, pg 2). Furthermore, how accurate must temporal memory be? If events are archived, are they merely ordered or do they contain some kind of time stamp to show how far apart each occurred from the other? If they are not, is the process that provides us temporal information precise or a rough estimate? Some researchers suggest that fitting an event within a temporal context may involve a degree of reconstruction or inference (Friedman, 1993), rather than a reliance on exacting information.

In subsequent sections, I will look at different ways in which one could account for temporal memory, and the current plausibility of these theories. First, it seems appropriate to take some space to address other ways in which time is thought to be represented by the human system. This has served as a starting point for some of the models I shall consider, notably our psychological experience of time (time perception or time processing), which some researchers argue underpin temporal memory.

1.1.2 Time in the brain

Regulation and biological clocks

Human biological processes are dynamically regulated on many levels, such as the hormone-driven reproductive cycle (Ellison, 2001). Biological rhythms may serve two principle kinds of functions.

The first, Internal Synchronisation, refers to the need to keep certain body-based processes temporally separated, for example incompatible chemical operations within a single cell or within a system, while keeping other processes synchronised, such as the production of a hormone and the availability of its receptor (an instructive recent review of this is Hastings, Reddy, & Maywood, 2003). The detailed research in this area has yielded evidence for regulatory structures which are clock-like in fashion, acting as a klaxon that hoots one set of processes off-shift as it sends another set to business. The accessibility of this concept has led to increasingly wide-spread use; for example, a recent study (Reppert & Weaver, 2000) discusses “clock genes” and a “timeless gene” in fruit flies.

The second, External Synchronisation, is the ecological function of ensuring activities occur at the appropriate time — essentially mapping behaviours against their (temporal) niches. For example, an action that tends to be successful at dusk, such as finding prey at a drinking hole, would be usefully deployed in the future at a similar point in the day-night cycle (Daan, 1995). External synchronisation is what concerns psychologists: how humans orient themselves with respect to time. The first broad way in which this is achieved is through circadian rhythms. These are the body’s method of mapping twenty-four hour day-night cycles, synchronisation being achieved through entrainment schedules imposed by exposure to periods of light and dark (Cermakian & Sassone-Corsi, 2002). The neural basis of the circadian clock is well-established, its locus being the suprachiasmatic nucleus of the hypothalamus (Hastings & Maywood, 2000). This system does not appear to be involved in the other way in which humans orient themselves to time, the moment-to-moment processing of the passage of time which underpins interval timing (Lewis, Miall, Daan, & Kacelnik, 2003). Despite this finding, which suggests two independent systems are responsible for circadian rhythms and interval timing, the relative success in identifying biological clocks in internal synchronisation and circadian rhythm have encouraged the same approach in interval timing research.

Time perception

Interval timing is the ability to judge with some degree of accuracy how much time has passed between two events (including a current and a past event), and is the type of time processing that psychology literature is concerned with. This ability is typically accurate, while showing a tendency to underestimate longer intervals (Eisler, 1976). One feature of the experimental literature is the *ratio rule*, that accuracy appears to increase as the ratio between the durations of two intervals

increases. “In virtually every kind of timing task, the decision to respond is based on the ratio rule of a currently evolving interval to a remembered standard” (Gibbon, Malapani, Dale, & Gallistel, 1997, p171). A great number of models exist that attempt to characterise these features, (Block & Zakay, 1996; Jackson, 1990) but dominant amongst them is the inclusion of some sort of clock mechanism.

The concept of an “internal clock” has been available in psychology since Hoagland (1933) proposed that our ability to estimate time was due to a chemical clock governed by body temperature. This idea still has some currency, and more recent research confirms that estimation of intervals of minutes is affected by body temperature (Campbell & Birnbaum, 1994), although there is less certainty regarding other periods.

Internal clocks are most popular, and have achieved most success, in modelling *prospective timing*, where subjects are warned they will be probed for the duration of events. In a recent review, Wearden (2001) explains that clocks have normally been conceived of as “a device in which the clock consists of a *pacemaker*, an *accumulator*, and a *switch* which connects the two” (pg 38, italics in original). A pacemaker produces regular emissions, equivalent to the ticks of an analogue clock, which are summed by the accumulator when the switch is open (i.e., after stimulus onset). Within the dominant model of animal timing, Scalar Timing Theory (SET), this device is accompanied by a *storehouse* for maintaining the durations of previous events, and a *comparison process* to allow judgment between the two (Gibbon, Church, & Meck, 1984). The pacemaker emissions may be produced by an “‘activation’ level that increases linearly in time ... so that particular threshold levels of activation mark particular moments in time” (Schöner, 2002), or the marking off of a full cycle of an oscillatory mechanism.

Another way in which an internal clock might be instantiated deviates from its mechanical namesake, while still capturing its function. The Church and Broadbent model (1990) uses a set of oscillators operating at differing rates. The phase of each oscillator is taken together and determines a code which represents the time elapsed: a *qualitative* encoding of time (Wearden, 1994) which Wearden exemplifies with eleven oscillators “starting at 0.2 sec and progressively doubling”, and two different durations; the example shows how by summing the values corresponding to the “on” oscillators the desired total is represented with the minimum of effort:

Osc. rate	.2	.4	.8	1.6	3.2	6.4	12.8	25.6	51.2	102.4	204.8
15 secs:	ON	ON	off	ON	off	off	ON	off	off	off	off
Sum:	.2 +	.4	+	1.6		+	12.8				= 15s
40 secs:	off	off	off	ON	off	off	ON	ON	off	off	off
Sum:				1.6	+		12.8 +	25.6			= 40s

(adapted from Wearden, 2001, pg 47)

In terms of instantiation in the brain, there is evidence to suggest a dopaminergic basis for the internal clock (e.g. Meck, 1996). Neuropsychological data highlights the involvement of two primary areas, the cerebellum and basal ganglia (Ivry, 1996). Cerebellar damage leads to deficits in the timing of motor (Ivry & Keele, 1989) and stimulus (Nichelli, Alway, & Grafman, 1996) timing. Basal ganglia damage leads to underestimation of time in the short term (O’Boyle, Freeman, & Cody, 1996) and overestimation for longer intervals (Malapani et al., 1994). There is also some limited evidence for some role for the suprachiasmatic nucleus of the hypothalamus (Cohen, Barnes, Jenkins, & Albers, 1997) and systems distributed throughout the cortex (Rao et al., 1997); damage to frontal cortex leads to underestimation of time intervals (Ivry & Keele, 1989) and variability in output is increased by damage to premotor frontal cortex (Lacruz, Artieda, Pastor, & Obeso, 1992).

It should finally be noted that as well as an involvement in time estimation and motor timing, some authors argue (Glicksohn, 2001) that some form of cognitive timer is required to underpin our conscious experience of passage through time; how, in the words of Augustine, “what is present may proceed to become absent”.

1.1.3 The appeal of timing to accounts of temporal memory

The above section describes the psychology of time processing — the ability to judge the duration of experienced events. What does this contribute to our understanding of temporal memory — the ability to organise past events on the basis of their time of occurrence? Some researchers argue it contributes a great deal, in that time processing actually underpins temporal memory: the clock-based information supplying the memory system with dedicated temporal information.

This step is not surprising. A great deal of evidence supports the existence of internal clocks, and many, though not all, models of timing include some sort of clock mechanism. Together with

the fact that similar entities are well-established in the biological sciences — enough to warrant the existence of a *Journal of Biological Rhythms* — this provides internal clocks with an authority that is inviting to command, especially for a younger science such as psychology. Moreover, theorists have advanced arguments for their involvement in memory on the basis of evolutionary need, just as such arguments have been advanced in the past to support biological clocks per se (Enright, 1970; Pittendrigh, 1967). Gallistel (1990) argues that temporal and spatial coordinates are essential components of animal memory records as they maintain the unity of remembered experience. J. R. Anderson and Schooler (1991) make an adaptive argument that the “need probability” of recent items is greater than more remote items, making it advantageous to have memory organised according to a temporal dimension. And given the ubiquity of internal clocks their use is seen as a non-costly way of enjoying these advantages.

As a consequence some researchers are involved in applying those findings from the timing literature to the domain of memory for temporal order, particularly the idea of a biological clock underpinning temporal memory. The proposal is not new and was mooted in the chronobiological literature some time ago (Enright, 1975), followed by successive endorsements (e.g. Biebach, Falk, & Krebs, 1991). Currently cognitive psychologists and cognitive neuroscience are examining the power such mechanisms would have in explaining human temporal memory. For example, G. D. A. Brown is a major proponent of models of memory where time plays an instrumental role. He has argued that

“The array of available [timing] models have all proved highly successful in accounting for empirical data in both animals and humans, and the success of such models can be seen as strong evidence for the existence of clock-like mechanisms (e.g. neurobiological oscillators) that can be recruited to underpin performance on tasks where representations of temporal duration are essential” (G. D. A. Brown & Chater, 2001, pg 91).

Essentially, these models argue for some kind of marker or time-code which is associated with or part of the memory for an event, which is used as a basis for organising memory or as a cue for determining the temporal position of events.

1.1.4 Limitations of clock-based timing

Before addressing models of temporal memory in the next section, I shall turn to evidence that casts some doubt upon how far internal clock mechanisms may be reasonably extended.

A metanalysis of forty-six measures of interval timing (comprising different tasks upon humans and animals) suggests that underlying these may be three or four distinct ranges of time underpinned by different neurobiological mechanisms; the authors also note that coefficient variations from these studies are typically high and suggest that other, non-temporal factors come into play (Gibbon et al., 1997). An analysis of a subset of these studies, those only concerned with human neuropsychology, reveal that “the size of the differences between patient groups and normals does not correlate well with the site of the lesion” (pg 178). This is suggestive of the possibility that there is no dedicated centre responsible for temporal cognition over multiple time-spans.

Another feature of temporal processing in humans is that it becomes poorer under conditions of divided attention (Fortin, Rousseau, Bourque, & Kirouac, 1993; Sawyer, Meyers, & Huse, 1994). This suggests that time estimation is achieved by using resources from a pool common to other tasks, rather than a dedicated reserve, and questions the degree to which temporal processing is an automatic process.

Essentially, evidence for timing mechanisms is compelling for the very short term (hundreds of milliseconds), credible for the short term (up to a second) but rather weaker beyond this. Due to this, researchers working in the neuropsychology of duration estimation have evinced skepticism for a biologically-based clock system conducting psychological time; take, for example, the declaration that “time, it would seem, is a cognitive construction” (Venneri, Pestell, Gray, Della Sala, & Nichelli, 1998, pg 169). Sources of information from short-term oscillator systems and bodily circadian cycles are likely to provide some information as to sense of time, but this cannot be the whole picture. Richelle (1996) raises the case of a speleologist (one involved in the scientific study of caves) who underestimated his stay underground at approximately half the true duration of over one hundred days. He argues that “subjective duration was influenced by cognitive factors” (pg 10). Glicksohn (2001) gives many examples of perceived duration being mediated by degree of absorbed attention, such as drug-induced hallucination, experiencing a romantic evening or reading an interesting novel. He also surveys the effects of procedures such as hypnosis (St. Jean, McInnis, Campbell-Mayne, & Swainson, 1994) — a phenomenon now considered by many to be

underwritten by the same processes that govern normal experience (e.g. Gandhi & Oakley, 2005) — where time estimation can also be affected.

Recognising the heterogeneity of observed temporal behaviours, I wish to argue that there are good adaptive reasons why clock-based timing systems are an appropriate and indeed vital resource for measuring the passage of short periods of time, but less so for longer periods.

1.1.5 Dynamics of short-term processes

There are two major behavioural domains where the duration of events is essential for successful function: speech and motor action. In both domains successful production depends upon the action of articulators at appropriate rates. Speed is essential for speech articulators to elicit the desired phonemes, such as the stop consonants such as “d” or “t” (Liberman, 1996); and swimming, leaping, and throwing a ball or rock all require instructions to be completed not just correctly, nor also in the correct order, but at the correct rates. Such similarity of demands and other requirements have lead some theorists to argue that speech arose from gestural communication (Corballis, 1999); other evidence includes the finding that Broca’s area is involved in the mirror neuron system involved in the perception, visualisation, and execution of manual action (Nishitani & Hari, 2000), and that Broca’s homologue in our primate relatives is concerned with manual gesture rather than vocalisation (Rizzolatti et al., 1996).

These actions — the tighten and release of leg muscles, or the flick of tongue against teeth — are rapid and the durations involved small. Although learning of action programs could in principle require the long-term retention of such durations, this would merely be a case of long-term storage of short periods, the measurement of which would still merely require oscillators built for small time ranges. In other words, there are very good reasons why we might be particularly sensitive to the precise passage of time in the very short term, as behaviour at this time level involves crucial dynamic components. Correspondingly, evidence for clock-based highly determinate temporal processing at the very short term should not be taken as evidence for such processing occurring at other time spans.

In ending this section, I shall quote from a theorist who has done a great deal to shape my thought on this subject:

“In addition to a strong disinclination to seek a single essence of time or time experience, I approach the psychology of time with another bias: A large proportion of the thousands of studies in this area concern what is called the perception of time....The dominance of time perception research is probably a consequence of a particular view of the psychology of time, one that I do not share, that time perception is the foundation of temporal experience.” Friedman (1990, pg 7).

As Friedman, this thesis will argue that time perception is not the foundation of temporal experience. Within this thesis I draw out evidence for, and make arguments for, an account of temporal memory that does not depend upon dedicated temporal information. Section 1.2 will lay out some various alternatives to how memories are temporally organised, and further pursue the imbalance of evidence for biological clock systems: that there is an abundance of evidence in the short-term but little to support it at longer spans. I shall argue that a cartography of a different kind is needed to frame the relationship between memory events, and that this cartography can be achieved to a reasonable level through the storage and reconstruction of order, rather than temporal, information.

1.2 Temporal memory: models and theoretical perspectives

Section 1.1 described the way in which memory traps the past, and the issue (central to this thesis) of how memory is able to preserve temporal relations between past events. It introduced the idea that this could be achieved via temporal codes yielded from biological clock systems. In this section, I will focus on the methods used to investigate temporal memory and the types of models which could account for temporal memory. I shall then examine the models that have been successful in characterising temporal memory at different time scales.

1.2.1 Different tasks, different demands

“It should be noted that the term *temporal coding* can be interpreted in three different ways: (a) coding an item’s position information in a serial list, (b) coding order relationships among list items, and (c) coding information about an item’s presentation duration.” (Tzeng & Cotton, 1980, pg 705).

Several different types of task have obtained popularity in measuring temporal order, having been designed to investigate subtly different aspects of this ability. This thesis will not dwell on the third type of temporal information — presentation duration¹ — as this, the subject of investigation in interval timing research, is a weighty problem in its own right. The other two notions of temporal coding, position in a list and relationship to another item, reflect two categories of the popular tasks of sequencing and serial recall, and judgments of relative recency/primacy.

Serial recall. Serial recall is “the most common tool for measuring verbal short-term memory” (Hitch, Fastame, & Flude, 2005, pg 247). More data upon the issue of order memory has been collected with this than with any other paradigm, due to its relative simplicity and high yield of data per trial. It requires subjects to reproduce a short list of items that they have just studied in a serial manner, typically by verbal reproduction of phonemic input, such as repeating back a six-item series of letters B–F–N–P–W–S. The serial recall task can easily be used to derive serial position curves, giving the accuracy of placement of items at each position, and error transposition curves, showing the likelihood of displacement of items to other positions. It is ideal for supplying answers to questions about the durability

¹ But see Experiment 10 where this ability is directly addressed.

of positional information, such as whether the positions of items in the first or last position are better remembered than those in other positions.

Item sequencing. In an item sequencing task items are presented in a given order and the object of the task is to reproduce that order. It differs from the serial recall task in that participants do not need to recall the items from memory, as these are presented at test, for example on cards which are revealed in a random array (see e.g. Shimamura, Janowsky, & Squire, 1990). This removal of the recall component enables the task to be utilised with longer sequences and over longer time-scales than the serial recall task, and can also be used to tap temporal knowledge of events not presented by the experimenter, such as autobiographical or public events (Bowers, Verfaellie, Valenstein, & Heilman, 1988; Shimamura et al., 1990). This is convenient if performance at temporal order tasks is to be compared across different time scales.

Judgment of recency. The judgment of recency (JOR) is a task wherein subjects study a sequential list, and then make a judgment as to which of two list members were seen more recently. It is found in two forms: interleaved and blocked paradigms. In the interleaved paradigm, study lists are interspersed with test trials, whereas the blocked paradigm renders the design into two components, a study list and a set of test trials. The interleaved paradigm is effective at collecting large amounts of data specifically on accuracy as a function of recency, but makes it difficult to investigate positional models as the integrity of a list is continually disrupted by test trial intrusions.

List probe. A recent addition to the repertoire of tools for investigating temporal memory is the list probe. This is essentially a recognition discrimination task where the candidates to be discriminated are sequences, rather than items. For example, the set A,B,C,D,E is serially presented at study and the test trial requires the subject to respond positively or negatively to a probe composed of simultaneously presented members, for example ACBDE. The list probe is used together with an item probe where a set of items is serially presented followed by a single item, to investigate item memory.

Event dating. A number of tasks have been developed to assess temporal memory for autobiographical and remote public events. Many of these revolve around dating such events. For example, the Dead or Alive test (Kapur, Young, Bateman, & Kennedy, 1989) requires subjects to make a dead-alive judgment for famous individuals followed for each “Dead” guess by a judgment of which decade they died in. Some studies demand more much more than

the decade; for example, Friedman and Wilkins (1985) asked for separate judgments of year, month, day of month, day of week, and hour of occurrence of various events. Most commonly a year-based, month-based, or date-based estimate is used.

Now/past recognition. There is a further kind of task which is often considered a test of temporal memory. This is the continuous recognition paradigm used by Parkin, Leng, and Hunkin (1990) and the more recent paradigm used by Schnider (2000; Schnider & Ptak, 1999; Schnider, Treyer, & Buck, 2000) to investigate confabulation. In the case of the Parkin et al. paradigm, a set of items are presented for study, and must be correctly identified and distractors rejected. As trials progress previous targets become distractors and vice versa, such that subjects must be able to distinguish the items they saw in the most current study list from those they saw more remotely. The Schnider paradigm adopts a continuous recognition task where subjects must identify items on their second or higher presentation in that run, whilst ignoring items only previously seen in earlier runs. In a sense such tests may be considered a special instance of normal recognition tests for familiar (e.g., words or everyday objects) items, distinguished by the fact that the researcher has determined the recency of previous exposure.

1.2.2 Types of models

Section 1.1.3 introduced a solution to the problem of maintaining temporal relationships between remembered events — the existence of time-codes based on chronometric signals attached to memories. There are however a number of other ways in which the problem could be solved. At this point it is worth introducing some of these solutions; I will keep to generalities about the principles that underly these approaches, rather than fleshing out specific models, as in the sections that follow I will discuss specific theories and the evidences amassed for them.

Chaining. Chaining models were an early attempt to explain our ability to retrieve order information about memorised sequences (e.g., Wickelgren, 1965), and have persevered as, if nothing else, a default explanation to overturn (e.g., Henson, 1998b; Lewandowsky & Murdock, 1989). Simply, every item is associated with its previous neighbour, and at recall each item acts as a cue for the following one, allowing under appropriate conditions the reproduction of entire sequences launching each successful recall from the shoulders of the last. In this form, the model is open to criticism on a number of fronts: a failure midway in the sequence should

consign the rest of the chain to failure, and in sequences such as ABCBEF, what leads to B cueing C in one instance and E in the other? More sophisticated models, such as the TO-DAM (Murdock, 1995), discussed in Section 1.2.3, attempt to overcome these shortcomings. In favour of chaining models is that they assume very little in representations beyond that which we know to be present — representations of the items themselves — and associations between them.

Positional coding. The positional coding models also have an extended history in order research (Conrad, 1965) and are in common use today (Henson, 1998b). Positional models assume that items are coded with respect to the positions that they take in a sequence; for example, item representations may be placed into bins coded 1,2,3 etc. Recall of the item may yield positional information, or the bins may be run through sequentially so eliciting the items. A strength of such models is that errors can occur without catastrophic failure, as the loss of one item does not necessitate the collapse of information about surrounding items.

Distance measures by proxy. These models suggest that our ability to place a given memory in time is the result of using one of its qualities as a metric of how distant it is from the present; this information is not tailored exclusively to this purpose but may be harnessed to perform this function, and (depending on the model) includes but is not limited to the vividness and trace strength of the memory. Comparisons between two memories would in effect involve comparing each to a reference point - the present - then judging which is more remote from this.

Distance measures by design. These models suggest that memory is chronologically organised, in that events are encoded in the brain such that events that are contiguous (fall immediately after one another) are coded side-by-side in the brain. This is the “tape recorder model” of Murdock (1974), the comparison highlighting the translation of temporal order and distance into spatial order and distance, as well as a corresponding cognitive ordering.

Location derivation. These suggest that a memory is assigned a place in time with respect to other memories or a wider context. Within this class are models that suggest we reconstruct temporal location using what information is available, principally contextual information taken from within the event memory itself, related memory traces, the autobiographical life-period and the general knowledge base, conspiring to produce a temporal window in which the event occurred.

Timing code. As discussed in Section 1.1.3, another alternative is for memory to be localised in time by using dedicated temporal information. This information is what is being invoked whenever appeals are being made to a time tag - an entity designed to contain specific temporal information. Judgments may involve comparing time tags directly or applying them to a reference time tag — the tag denoting the present — and then comparing the two discrepancies. Members of this latter case are conceptually very similar to the Distance Accounts (a case of distance by design), and indeed some reviewers have chosen to class them together with those models (e.g. Friedman, 2001). Timing codes may also underwrite positional accounts, or suggest some kind of location framework (Yntema & Trask, 1963). The involvement of dedicated timing information binds each of them together, and it is conceptually useful to distinguish these from accounts which do not require such information.

1.2.3 Temporal context in Short term memory

The sequencing and temporal ordering of memory items has been more heavily researched in short-term or working memory than in any other domain. This is partly due to the use of data-rich paradigms such as serial recall that yield reliable results and large sets of informative data. Such paradigms also provide opportunities to tap processes analogous to both speech and motor activity, as they capture the need of these processes to maintain the order of set items over short timescales: this provides an incentive in furthering our understanding of these processes. This has resulted in an abundance of models; for example, Neath and Suprenant (2003) discuss ten models of serial order memory. Such models are often designed to pick at specific issues such as the role of response suppression in preventing the repetition of items in repeated sequences (Farrell & Lewandowsky, 2002), or phonological confusability effects (see e.g. Lange & Oberauer, 2005). They address the peculiarities inherent to short-term memory operations. This does not speak to the issue of how we tend to order past events, except to suggest reasons why this task may be achieved differently at different time scales.

Some models that primarily attempt to characterise order memory are also bounded by their focus on short-term memory. One example is Page and Norris's (1998) Primacy model. This proposes an elegant mechanism by which ordered recall is achieved: activation of item nodes occurs with each successive presented item, decreasing linearly across items to produce a primacy gradient, an example of a distance measure by proxy (see Section 1.1.3). An example of this is illustrated in Figure 1.1. Over time activations decrease but the primacy gradient is maintained. At recall the

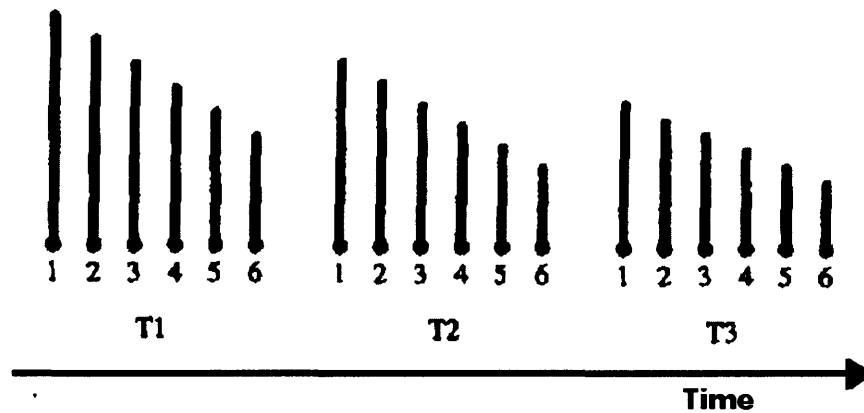


Fig. 1.1: Example of the primacy gradient that underpins the Primacy model. The gradient is preserved despite activation decay over time. Taken from Page and Norris (1998).

mechanism cycles through item nodes, selecting for recall and then suppressing the most active item. They illustrate that such a mechanism, coupled with natural decay of activations, results in simulations that mimick actual performance, in particular the primacy and recency effects — superior performance for the first and last items — that characterise most investigations of serial recall. However, they themselves caution about attempts to generalise from this model to other timescales.

There is a great deal of experimental evidence that indicates both the phonological nature of the memory system underlying performance in this task and the fact that representations in this memory system are extremely labile...For this reason, our model, like Baddeley's, should not be thought of as being applicable to tasks involving serial recall after significant delays (Page & Norris, 1998, pg 762).

Some models, however, either leave their extension to other time spans open to empirical investigation or explicitly claim a mechanism that is scale-invariant. The former include the various chaining and positional models used to account for short-term data; the latter attempts to interpret memory through a temporal structure, such as the models proposed by G. D. A. Brown (G. D. A. Brown & Chater, 2001; G. D. A. Brown, Preece, & Hulme, 2000).

Chaining models are a type of model deployed in short-term memory research but also generalisable to other spans of memory, positing, simply, that inter-item associations provide the information required to retrieve order information. Recent work appears to undermine the plausibility of chaining models to fully account for short-term data. Henson, Norris, Page, and Baddeley

(1996) demonstrate that when confusable and non-confusable items are alternated in a sequence, a “sawtooth pattern” is produced, wherein accuracy for the non-confusable items is better than for their neighbours, and performance for the former is under some conditions unaffected by the presence of the latter. This is inconsistent with a chaining approach, wherein performance for one item should affect performance on its neighbour, producing an averaging rather than only the observed sawtooth. Henson (1998a) demonstrates that higher errors due to repetition of items are not the consequences of errors following repeated items — evidence for selecting the wrong part of the associative chain following the ambiguous item — but due to errors for the repeated item itself. More complex models (such as the TODAM model developed by Murdock, 1995) have emerged to avoid these sorts of criticisms; however, it appears that these accounts are being dropped in favour of variants that remain essentially associative but involves information from all previous items, rather than the immediately prior neighbour, forming less of a chain than an increasingly branching web (Murdock, 2005). Additional evidence against this are the better performance in JORs when items are more separated than less (Hacker, 1980); one would expect associative order information to better survive between items that are separated by fewer steps.

These models have tended to be superseded by Positional models, in which each item is linked to a representation of its position within the sequence, rather than to other items within the sequence. These carry weight on the basis of several experimental findings. Errors within lists tend to show transposition gradients, in that the likelihood of an items placement is highest for its correct position, and slopes off as the degree of misplacement increases (Estes, 1972). Intrusions from previous lists tend to occur at the same position that they were studied in the other list (Conrad, 1960). Such models must attempt to account for the bowed shape of the serial position curve, (e.g. Crowder, 1972) — the primacy and recency effects mentioned earlier, where items from the beginning and end of lists are more accurately recalled in both serial and free recall. One recent model which has been successful for accounting for this as well as other features of the short-term serial position curve is the Start-End Model (SEM) proposed by Henson (1998b). His model proposes that we are able to reproduce items serially as a result of encoding positional information with each item, using a bi-vector feature system (x,y) to code position. These vectors code proximity of the item to the start and end respectively of the sequence it resides in. Items near the start have a distinctive code — a very high start coding coupled with a very low end coding (approaching 1,0) — as do those near the end (approaching 0,1), whereas items towards the middle of a sequence possess codes that are less distinctive (typically, feature models consider a vector of 0 to contain no information). This is presented in Figure 1.2.

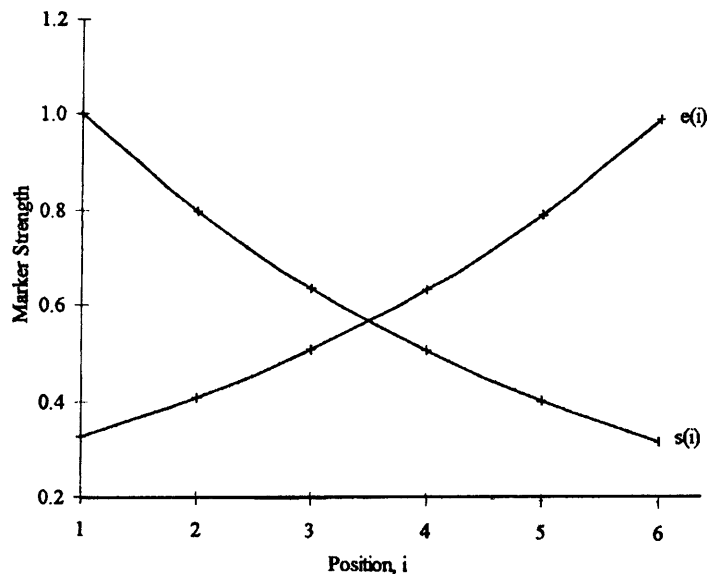


Fig. 1.2: Start and end marker strengths in a six-item list within the SEM. Taken from (Henson, 1998b).

This enables the model to account for primacy and recency effects, and also explains the finding that intrusions of the end item from a previous list fall at the end of the current list even if the lists are of differing lengths (Henson, 1999). The SEM in principle could account for ordering of items at longer time levels, as long as dual coding is possible at those spans. As a consequence, I test the predictions of this model in Chapter 2.

Other positional models do not use a dual-code system, but rely on chronometric information to underpin their positional models (G. D. A. Brown et al., 2000; N. Burgess & Hitch, 1999). N. Burgess and Hitch (1999) address serial order within the phonological loop and consequently may be seen as another explicitly delimited model of STM, rather than an attempt to characterise all temporal order judgments. Given the focus of this thesis it is nonetheless reasonable to describe the workings of the model more fully. It attempts to account for a number of features typically found in serial recall data, including the bowed serial position curve, temporal grouping effects and modality effects. Their model proposes a “moving window” that accompanies events in real time and confers upon them positional information; this information is suggested to arise from the operation of an oscillator system (Treisman, Cook, Naish, & McCrone, 1994) producing a time-dependent dynamic signal, in a manner similar to that presented in Figure 1.3, using the analogy of clock-faces to stand in for the dynamic signal. Such an account fits with the temporal grouping patterns found by interpreting them as the result of entraining multiple rhythms (Henson & Burgess, 1997). N. Burgess and Hitch give an account of how their proposed mechanism would produce serial recall patterns similar to those found in real data: the context-timing signal is

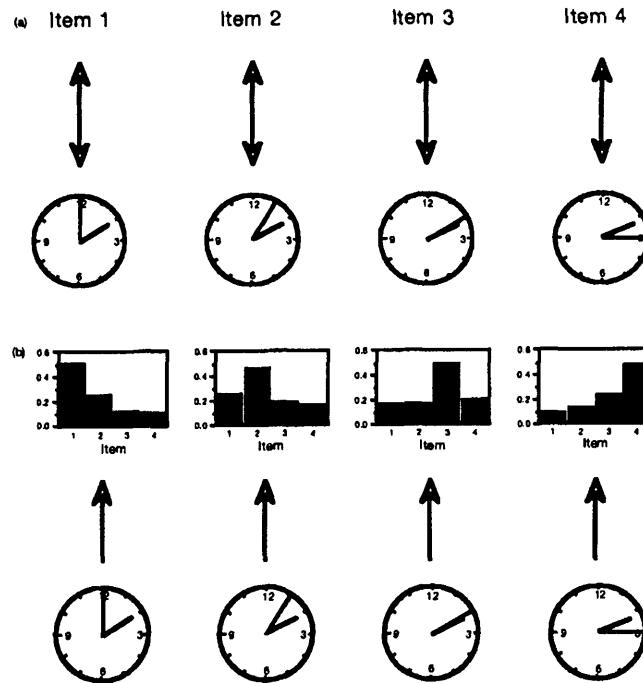


Fig. 1.3: (a) The association of oscillator signals and successive items in a study list. (b) Order of items retrieved by replay of the clock, activating at each state the item most directly associated with that state. Taken from G. D. A. Brown et al. (1999).

rewound to its original state at the beginning of presentation of stimulus, and evolves through its successive states, activating the items associated with each state leading to their reproduction.

N. Burgess and Hitch explain the serial position curve by appeal to fewer positional representations that can be confused for the first and last few items — an edge effect. This differs from the time-code models of G. D. A. Brown. They are able to fairly closely model serial position curves based on real data, although their model exhibits a weaker primacy effect than is actually found.² Given the bounded nature of the model, it will not be directly tested in subsequent chapters. It does however give a sense of the sophistication that timing-signal accounts have acquired in accounting for STM.

G. D. A. Brown has proposed a model of memory underpinned by time-codes that attempts to account for memory across all time scales. This merits a separate section (1.2.6). An earlier model of his which aims more narrowly at order memory primarily at shorter time periods (G. D. A. Brown et al., 2000). This model, the OSCAR (OSCillator-based Associative Recall) model utilises a series of oscillators similar to those described in Section 1.1.2 which provide a timing signal which

² This appears to be due to a reluctance to over-state the contribution of inter-item rehearsal to connection weights, which they argue to be the basis of the steep primacy effect produced in the primacy model (Page & Norris, 1998).

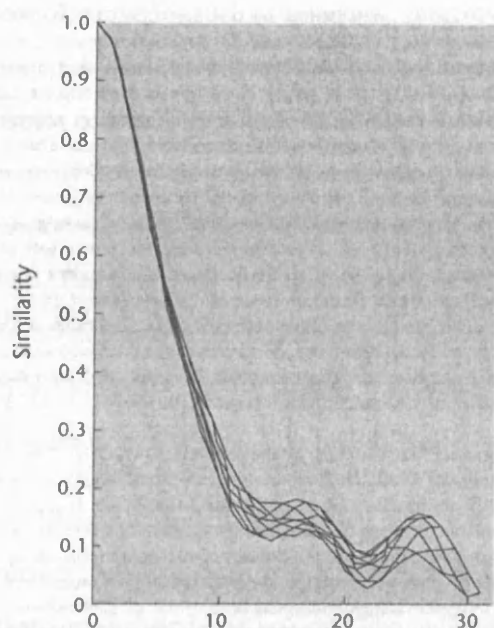


Fig. 1.4: A representation of the similarity function of the OSCAR contextual-clock system. Taken from G. D. A. Brown and Chater (2001).

is associated with items in a sequence. Much like N. Burgess and Hitch's model, the clock then rewinds and runs forward through its positions, bringing with it the successive associations to the items in the original sequence. G. D. A. Brown et al. make explicit how relative recency judgments are achieved: the difference between the current oscillator state and the states of the codes on the two items: the more similar code is the more recent. In their model, the similarity function of the timing signal is such that it changes more quickly over short distances than over long distances, as seen in Figure 1.4. This is critical as it allows the model to account for the recency effects typically observed in short-term memory: two events close together and recent have more distinguishable tags than two remote item at a similar spacing. It also means that two events from the recent past should be easier to distinguish than two events with the same lag from the more distant past — small differences are amplified in the short-run but tend to being negligible in the long-run. This computational convenience becomes the foundational principle of G. D. A. Brown's subsequent model, the SIMPLE model, discussed in Section 1.2.6.

1.2.4 Temporal context in Long term episodic memory

Relative to STM, LTM order memory has been underresearched. The obvious reasons for this include the relative simplicity of STM order tasks which involve simple stimuli and can prevent the

use of strategies such as rehearsal, imagery and narrative structure, and the obvious application of research at shorter durations to clear low-level psychological issues such as speech production and motor control. Of course, LTM order memory research does allow us to answer important questions, namely how we manage to order items at this particular timescale, and whether processes driving performance at other time scales continue to apply. The issue is of intrinsic importance. Despite this, the literature remains sparser, with relative popularity during the early days of cognitive research towards the middle of the last century waning to a more subdued level. One area in which this time-scale has undergone continued research is in the neuropsychology of context memory, discussed in section 1.4.3 and addressed more fully in Chapter 5.

Distance models, suggesting that temporal judgments are achieved through the use of some memory quality serving as a proxy for distance from the present, have an intuitive appeal that has demanded their investigation. The judgment could draw on memory strength (e.g. Hinrichs, 1970) or vividness, or a composite of a variety of memory features such as the generalised strength quality conceived by Dennis and Humphries (1998). On balance, empirical work has tended to undermine distance models as the primary method of making judgments. Especially memorable items tend not to be misattributed as more recent but more accurately placed in time (Hintzman & Block, 1971; Underwood, 1969). Additionally, it has been demonstrated that healthy participants are able to make judgments of recency even when generalised strength is altered by manipulating frequency of item presentations, such that remote items were presented more times (Dennis & Humphries, 1998; Huppert & Piercy, 1978; Meudell, Mayes, Ostergaard, & Pickering, 1985). However, when items are unfamiliar it does appear that generalised strength is used to a greater extent, as these items are more likely to be falsely judged as recent if presented multiple times (Chalmers, 2005; Dennis & Humphries, 1998).

There is some evidence that even familiar events are judged on generalised strength if subjects are forced to make rapid judgments. Friedman (1996) recounts a study in which subjects were required to rapidly distinguish between recent (less than one year) and more remote events using button presses. Participants reported relying on vividness and the amount remembered of events, and showed a sensitivity for very recent events (within three months) that dropped away to a similar level, suggestive of reliance on information that changes at a decelerating rate with the passage of time. When subjects are asked to make responses by administering force to a grip meter, grip force correlates with vividness better than normal date estimates (Kemp & Burt, 1998); this suggests that distance is a criteria that is employed in temporal judgments, but only in atypical circumstances, whether these be due to neuropsychological deficit, time constraint, or an

unusual response mechanism. It should be noted that these last two studies deal with memories of events a year or more away, and that there is reason to believe that this should be distinguished from experimental LTM spans, as explained in Section 1.2.5.

Chaining offers a distinct but similarly intuitive account of temporal memory. Similar to its status within STM, it appears unlikely that chaining can offer a full account of temporal memory within LTM. One reason for this is that within the longer term we may wish to make temporal judgments on events that may have occurred in different contexts and therefore are unlikely to be part of a single linear chain of association; consider making the judgment of whether I more recently answered the phone or made a cup of tea. Moreover, as in LTM, JOR decisions tend to be easier when the judged pairs were studied at a greater separation, first shown by Yntema and Trask (1963) using an interleaved paradigm; Tzeng and Cotton (1980) used a study-test JOR paradigm to demonstrate that performance when inter-item distance was 10–19 positions exceeds that where that distance was between 0–9 positions.

The study-phase retrieval model proposed by Tzeng and Cotton (1980) is a distinctive account of temporal order memory: it suggests that under normal circumstances as we study an item in a list we are also rehearsing prior items. This results in one-way associations being generated between the currently presented item and the retrieved prior item. This model suggests that items are more likely to cue prior items that are related, and thus we would expect temporal order judgments to be superior for related items, a prediction born out by their and other research (Tzeng & Cotton, 1980; Winograd & Soloway, 1985). This model has also been advanced by Winograd and Soloway (1985). The study-phase retrieval model will be discussed in more detail in Chapter 2. For now it remains to state that this manages to capture some aspects of LTM order memory, but in a similar manner to the other models described in this section, does not appear to decisively capture it in its totality.

An issue which models of LTM must account for is the degree of intentional involvement that buttresses accurate temporal judgments. Early evidence of better than chance performance on surprise temporal memory tasks (e.g., Hintzman & Block, 1971; Proctor & Ambler, 1975), and lack of effect of intentional instructions (e.g., Toglia & Kimble, 1976) lead to the claim that temporal information was automatically encoded (Hasher & Zacks, 1979). Counter to this, subsequent work has demonstrated that participants' strategy use affects accuracy in temporal judgments (Michon & Jackson, 1984) and that when more rigorous standards of intentionality are applied, intention effects are shown (Naveh-Benjamin, 1990).

1.2.5 Temporal context — beyond episodic memory? Autobiographical memory

Section 1.1 made reference to the way our temporal memory allows a coherent sense of autobiographical past. This issue needs deeper discussion, as autobiographical memory as currently conceived is less an instance of episodic memory and more a system within its own right. Conway considers episodic memory as a system of representations that do not endure beyond a day or so, and which requires consolidation/integration (perhaps during sleep) to remain available as part of a further system, one comprising autobiographical memories. This is contrasted to autobiographical memory, “a type of memory that persists over weeks, months, years, decades and lifetimes” (Conway, 2001, pg 55). This considers episodic memory as a type of “experience-near” knowledge which may provide important information in the period that follows the event, but which may have no further bearing upon the future goals of the owner of the memory system. Remembering whether I have had dinner is of some relevance tonight, but, given a week, is of no benefit to know either way. Only those pieces of information that merit permanence are retained as autobiographical memory, such as an afternoon spent deep in the Namib desert where my water supplies run out. Such memories may be stored as visual images (climbing sand dunes), contribute to semantic personal facts (visited the oldest desert in the world), and provide and orientate personal goals (always carry water).

Under this framework, then, the temporal organisation of lifetime memories may present a third distinct case to short-term and episodic memory. The priorities laid by the autobiographical memory system would depend upon the various functions it serves. Autobiographical memory allows us to develop “opinions and attitudes that guide one’s behaviour....to ask new questions of old information in order to solve problems in the present, and to predict future events” (Bluck, 2003, pg 115) — its directive function. This carries a common purpose with LTM. However, the other functions that autobiographical memory accomplishes are absent from LTM, and imply a divergence of demands on how they are respectively organised. One is the contribution of the past to the idea of the self. One component of the self is the “extended self” (Neisser, 1989) or “narrative self” (Dennett, 1991), the idea of a continuous “I” that proceeds through events which reflect and alter it. In a recent review, Gallagher (2000) argues that evidence from the neurosciences is consistent with Hume’s (1739/1975) charge that this experience of self is drawn from multiple distributed sources and ultimately “a fiction, albeit a useful one because it lends a practical sense of continuity to life, but a fiction nonetheless”. This is a claim that autobiographical memory involves reconstruction of events, which may involve the use and finessing of key themes and events

to produce a coherent experience of extended time periods: it needs to have some correspondence to actual events, but may be “a bit fictional” (Gazzaniga & Gallagher, 1998, pg 713) nonetheless. This creates a tension between the demands of autobiographical memory that is absent in long-term episodic memory: the demand to preserve information that corresponds to real past events and the demand to maintain an information structure consonant with a coherent narrative self.

Research into temporal memory for autobiographical events, and public events concurrent to autobiographical periods, typically uses dating paradigms to investigate performance. Autobiographical events could be organised like a calendar, by their date or some temporal marker. Alternatively, they could be organised according to topics, such as “good events”, “bad events”, “boring events” and so on. Alternatively autobiographical memory could be organised in a more sophisticated way, with layers of knowledge each organised in a somewhat different way. Entities in one layer could be sequentially ordered, whereas others may be organised thematically (S. J. Anderson & Conway, 1997). Such a system has been characterised as containing specific memories, general events and lifetime periods, each organised in a different manner according to the functions each performs (Conway & Pleydell-Pearce, 2000).

Empirical evidence suggest that remembered events are dated better than chance but errorfully, often showing fairly large deviations from true dates (N. R. Brown, Rips, & Shevell, 1985; Burt, 1992; Kemp, 1994; Underwood, 1977). The time of events is a poor cue for recall of autobiographical events (Brewer, 1988). Similarly, feelings act as a poor prime for autobiographical events (Robinson, 1976) whereas cueing with life periods proves effective (Conway & Bekerian, 1987). This and other evidence suggests that chronological or simple topic-based organisation of autobiographical memory is implausible, and that a hierarchical system such as that suggested by Conway and Pleydell-Pearce (2000) is a better account.

If we do not accept a calendrical or in some sense chronologically ordered autobiographical memory then how are temporal order judgments achieved for these kinds of events? Those theories that currently render the best accounts fall into the class of location-based theories, particularly those that presume some degree of reconstruction. Events are embedded into a temporal environment relative to other events: a celebration occurs during school graduation year, or to commiserate after a depressing event. This position will often be inferred by accessing information about the event itself (the celebration may have been an 18th birthday party of a friend) — using internal context information from the event — or from how the event related to the wider context (guests at that party were people known during the final days of school) — using external context information

from how the event and the wider environment were related. “It is possible that date reconstruction is begun only when people fail to recover a calendar date for the target event. However, because explicitly encoded dates are rare (N.R. Brown et al., 1985; Underwood, 1977), date reconstruction should be common” (N. R. Brown, 1990, pg 301). Evidence that location-based theories offer a better account of the data is presented by Friedman (2001), and includes the fact that temporally contiguous events but unrelated events do not cue one another. Contextual, rather than temporal relations, appear to be a prerequisite for effective cueing. Also consistent with this are scale effects (Friedman, 1987; Friedman & Wilkins, 1985), where judgments can be correct on a fine-grained metric (such as the hour of occurrence) but wrong on a broader metric (such as month or year). This suggests that judgments are not made using a quantitative measure, such as temporal codes or distance proxy measures, but are localised using the information that is available, for example the activity being engaged in, amount of sunlight or physical location.

For location information to translate to accuracy in a dating task, it is necessary that a given event be localised with respect to a particular kind of event or period; specifically, one that is associated with specific, formalised temporal information. If I am asked to date a celebration and can confirm it occurred after a break-up during a time studying for a degree before my cousin’s wedding and in between living in two residences — but could not provide an idea of the dates of any of these — then I am no closer to answering the request. Periods of time that are associated with formalised temporal information can arise from public life, for example, the dates a political party were in power, but are more commonly associated with life periods that individuals live through. The reason for this is simply that we tend to overlearn and consolidate information about major periods in our life, in order to fulfil both self functions as well as directive (e.g. to provide accurate information on a curriculum vitae) and social functions (in reminiscence with friends and family). This is exemplified in Figure 1.5 which depicts a section of an autobiographical memory structure which includes lifetime periods, general events and a phenomenological record of specific sensory and affective information. I will discuss in more detail the issue of life periods and their role in aiding dating judgments in Chapter 4. Single events that provide temporal information are termed temporal landmarks, and discussion of these demands some further detail.

Temporal landmarks

Shum (1998) describes three types of events that can constitute temporal landmarks: widely-known public events, personal events and calendar reference points. Public events have to be vivid and

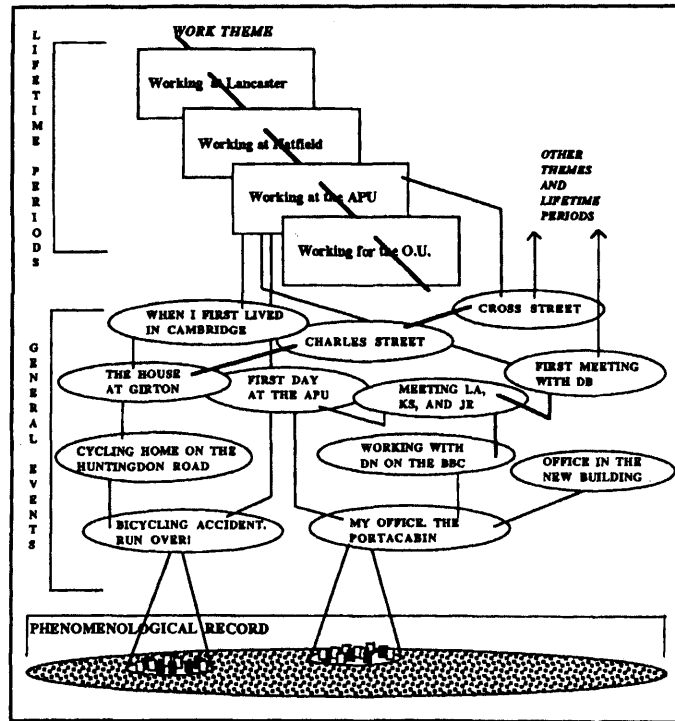


Fig. 1.5: An example of the hierarchy of autobiographical memory including lifetime periods, general events and the phenomenal record. Taken from Conway (1992).

capture the popular imagination to act in this role, forming a class of memories termed “flashbulb memories” (R. Brown & Kulik, 1977), which may be the consequence of a special encoding mechanism distinct from that leading to other enduring memories (in line with R. Brown and Kulik’s original proposal) but are more likely to involve a combination of factors including both how the event is encoded and how it is subsequently rehearsed (Bohannon & Symons, 1992; Conway et al., 1994). The kinds of personal memories that tend to act as temporal landmarks are those that mark a first event, which Robinson (1992) has argued are crucial elements of personal histories, delineating the entrance of significant others into their history (for first meetings with friends/partners), the formalisation of a working identity (for first days in jobs or novel achievements such as winning a first court case), or the establishment of a local identity (for moving to a new environment). These functions are assisted by the fact that new experiences necessitate novelty, which in itself is a spur to attention and subsequent reminiscence, and are provocative of emotions both positive and negative, which can also lead to better memorability (Pillemer, 1984 and see also Cahill & McGaugh, 1995 for a description of the neurological and psychopharmacological underpinnings of this feature). Calendar features can include the end of a year, public holidays, term dates, and other cyclical features such as the end of financial year. Shum includes lifetime periods in his taxonomy but there is some value in separating temporal landmarks as discrete events from life

periods as a backdrop in which important events may fall. Research suggests that overwhelmingly the landmarks that people choose to offer fall from the latter two categories of personal and calendrical landmarks, such as the transition from high school to college (Kurbat, Shevell, & Rips, 1998) rather than flashbulb memories (Shum, 1997, cited in Tourangeau, Rips, & Rasinski, 2000).

Temporal landmarks are important in two ways: they may be used as cues to access autobiographical memories (Robinson, 1986), and they may be used in order to make inferences about the time of other events. They were identified as crucial in this latter role by early theorists in the field, such as Ribot (1882); his position is summarised by Conway as follows:

“The metaphor that drives Ribot’s theory of autobiographical memory is that of visual perception. In particular, Ribot asks ‘How do we locate ourselves in space?’ and his answer is that we do so by referring to a point, the distance and orientation of which we already know. In the case of recollective memory the same principle applies and we localize a memory in time by employing reference points, the (relative) date of which we know. For Ribot then autobiographical memory is indeed a vision in time” (Conway, 1990, pg 18).

The appeal to spatial metaphors underscores how this concept necessarily sits within a location conception of temporal memory: a memory that noticeably falls before or after a temporal landmark, or between two, can be localised to some degree of accuracy. Friedman and Wilkins (1985) describe many participants making estimates about the birth of Prince William on the basis of the known date of the marriage of his parents, and the fact that they knew that it fell somewhat after that event. Estimates of the frequency with which people use landmarks to date events varies from 10% (Burt, 1992) to nearer 30% (Friedman, 1987; Thompson, Skowronski, Larsen, & Betz, 1996); this variation may be due to the way questions are phrased. These studies show that temporal landmarks are an effective way of estimating dates, only bettered by direct retrieval of the date.

1.2.6 *Oscillators and temporally organised memory*

In the previous sections I have shown how different accounts tend to be favoured in different memory domains. All-purpose generalised accounts tend to encounter problems in one or more domains on account of characteristics of the data that are peculiar to that domain. In the face of this, generalised explanations continue to be proposed, as their success would satisfy parsimony

and stand as a highly valuable solution. One such account, of the temporal ordering of memory items and of memory organisation itself, is that of temporally organised memory.

There are two ways in which memory may be temporally organised. The first is that memories may be spatially distributed in the brain according to their order of encoding. My memory of the events of 21st December 2005 and 22nd December 2005 are adjacent to each other in the neural substrate. This is the “tape-recorder model” of Murdock (1974). The durability of this way of thinking about memory organisation, which may or may not be accountable to its formalisation into models such as Murdock’s, can be seen in its infiltration into neurological research. For example, Doty argues that “date-specific temporally continuous spans of irretrievability suggest a chronotopic mapping of times past...Perhaps the hippocampus is a microminiature quipu [record-keeping device], continually knotting the present and stringing it anatomically into the past” (1990, pg 151).

Murdock’s model has the benefits of being both simple and offering the clear prediction that neurological damage should lead to memory loss of temporally adjacent events. It is the case that memory-impaired patients often show a predictable pattern of memory loss that follows a temporal gradient (Alvarez & Squire, 1994; Damasio, 1989; Hodges & Graham, 1998); however, gradients tend to be fairly linear, with increasing loss either for more recent (Kopelman, 1989) or remote events (Hodges & Graham, 1998). It is not the case, for example, that patients in the literature exist with the following pattern: brain damage suffered in 1998, patient presenting with normal memory for childhood–1990 and 1994–8 but shows an amnesia for the intervening period. The time-sensitive patterns that do exist can be better explained by recourse to other explanations that do not involve an anatomical temporal organisation of memory. The standard temporal gradient (remote memories preserved, whereas recent ones are lost) is explicable under a hypothesis where the hippocampus is critical as a holding pen for new memories before they are weaved permanently into the distributed neural substrate by consolidation processes (Alvarez & Squire, 1994; Damasio, 1989). Under the same hypothesis, the reverse gradient seen in semantic dementia patients is congruent with a preservation of the hippocampus coupled with atrophy of the neocortex, where consolidated memories are assumed to reside (Hodges & Graham, 1998). It is also the case that more recent research challenges the extent to which temporal gradients are observed in patients, and deficits may be flatter than have previously been considered (Westmacott, Leach, Freedman, & Moscovitch, 2001). In any case, the neurological record does not offer evidence that would support this proposal of temporal organisation of memory. Another prediction, that temporally contiguous events should be easy cues of one another, tends not to be the case (Friedman & Wilkins, 1985).

Beyond this, there is little cognitive data that would support this account against any other model; Friedman (2001) notes that its predictions are easily explained under other existing explanatory frameworks.

An alternative proposal is that memory is temporally organised by dint of each memory being marked with temporal information, like a ISBN number on a library book. Memories need not be stored in temporally ordered lots, but these temporal markers are a fundamental way in which memory is searched and retrieval is accomplished. Just as chronotopic mapping has been a popular conception of memory organisation, so has the related idea of memories tagged with temporal information — indeed, at the end of the chapter from which I have cited above, Doty suggests that the hippocampus is involved in tagging memories with sequence information, despite the fact that this would appear less than necessary if temporal relations were mapped spatially. Damasio, Graff-Radford, Eslinger, Damasio, and Kassell (1985) also refer to time codes with little expansion of what is meant by this. The idea of time-tagging has also enjoyed currency within cognitive psychology, suggested by Yntema and Trask (1963) and subsequently endorsed by others (Anisfield & Knapp, 1968); it should be noted that in many cases it is unclear what entity this actually refers to; in some cases the use of the term is at odds with this formulation (see e.g. Tzeng & Cotton, 1980, wherein temporal code is taken to mean “knowledge of order information about the memory traces”).

G. D. A. Brown is currently supporting a model which is intended to “capture directly the notion that a central dimension underpinning the representation of all episodic memories (over both short and long time-scales) is the amount of time that has elapsed since that memory was laid down — the temporal distance of the memory.” (G. D. A. Brown & Chater, 2001, pg 95). This model has the virtues of escaping several of the problems of Murdock’s (1974) account. It does not require temporally adjacent items to be stored together, nor would it require that events always act as successful cues of temporally adjacent events. One could discount the efficacy of the code under certain conditions and claim that it is not the only organising principle, but, as is in fact claimed, that “time is an important underlying dimension of memory” (G. D. A. Brown & Chater, 2001, pg 97). G. D. A. Brown’s model, the SIMPLE (Scale Invariant Memory, Perception and LEarning) model, has not been published in a complete form so its precise workings cannot be fully described here. It is described in some detail in G. D. A. Brown and Chater (2001), sufficient to draw out some of its underlying principles. The model attempts to formalise a suggestion made by Crowder (1976), which is quoted by G. D. A. Brown and Chater and reprinted here:

"The items in a memory list, being presented at a constant rate, pass by with the same regularity as do telephone poles when one is on a moving train. The crucial assumption is that just as each telephone pole in the receding distance becomes less and less distinctive from its neighbours, likewise each items in the memory list becomes less distinctive from the other list items as the presentation episode recedes into the past. Therefore, retrieval probability is assumed to depend on discriminability of traces from each other" (Crowder, 1976, pg 462).

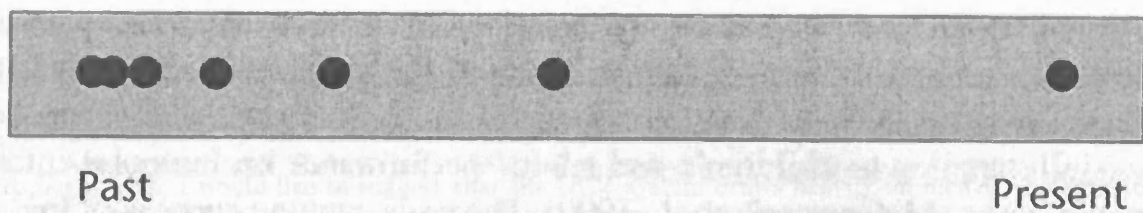


Fig. 1.6: The representation of items in memory as a consequence of the ratio rule. Application of the rule results in items becoming closer to each other on the temporal dimension as they recede into the past. Taken from G. D. A. Brown and Chater (2001).

This principle is represented in Figure 1.6. The SIMPLE model takes this principle and applies it in a fairly sophisticated way, with successful recall considered to occur similar to how categorisation discrimination tasks take place in multidimensional space (for example, at rapid presentation rates each item encoded suffers interference not only from the immediate temporal neighbours, e.g., B and D for the item C in sequence ABCDE, but also A and E). Nevertheless, the basic principle holds: "the retrievability of items from memory will have ratio-like qualities" (G. D. A. Brown & Chater, 2001, pg 96). This ratio rule leads to the same outcome as those discussed in Section 1.2.3 for the OSCAR model: it predicts that items separated by a short time in the recent past will be easier to distinguish between than two items separated by a short time in the more distant past. This principle is examined experimental later within this thesis, and I shall discuss it further in Section 1.3.

1.3 *Accounting for LTM (episodic) order memory*

I have given an account of the various models that could account for temporal memory. The concept of time-codes attached to memories, introduced in Section 1.1.3, is instantiated in a number of models. These tend to arise from attempts to account for order memory in STM, but although some of these are explicitly bounded to address only STM (N. Burgess & Hitch, 1999), others are more expansive (G. D. A. Brown et al., 2000) and most recently a model has been proposed to account for memory across all time-scales using a temporal organisation account (G. D. A. Brown & Chater, 2001). Sections 1.3.2–1.3.3 will present an argument against this approach. Following this, in Section 1.3.4, I will argue that a more fruitful approach may be to examine some of the processes proposed by the location reconstructive account endorsed by Friedman (2001) and others. To begin with, I would like to suggest that the LTM system draws heavily on memory content to make inference, and the argument that it relies on extra-event dedicated information is implausible, using a method of philosophical assessment known as the Bergsonian Approach.

1.3.1 *Bergsonian intuition on dedicated temporal information*

I will argue below for a special need for temporal and order information in STM. LTM involves no similar set of demands. If one experiences a sequence of events, it may be critical to know the relative order of a few events (that you sent an important email before the network outage, not after) but these will tend to be either significant in their own right, or meaningful with respect to one another. If I cannot remember having my coffee before or after sending the email, this is unlikely to have any effect. Cases where this is untrue (for example, retracing events in a murder investigation) are the exception, rather than the rule. There is evidence (see Section 1.2.4) that temporal judgments are reliant on strategy use and intentionality. I argue that such judgments ultimately rely on memory information and inference, and we do not have access to disembodied temporal information.

To attempt to further draw out this assertion, I shall take a Bergsonian approach to the plausibility of extra-event temporal information. Bergson (1949) describes intuition as “the kind of intellectual sympathy by which one places oneself within an object in order to coincide with what is unique in it”. This approach can be used to attempt to ascertain if two entities are actually different, that is, to distinguish between them (see, e.g., C. Williams, 1998). I wish to continue an example I began in Section 1.1.1, an event entitled ISWOPPED (I Spilled Wine On Professor

Plum's Easel Debacle). I would like to consider ISWOPPED2, a second embarrassing event all the worse for occurring once again at the distinguished Profs house, in front of the same set of guests, at a dinner party the following week. Assume that even the emotions and experiences felt were the same, with no reference even to the events of ISWOPPED (e.g., "not again!") One could not distinguish ISWOPPED and ISWOPPED2 on the basis of their spatial location, or in this instance on the gross detail, yet one could not doubt in principle they were separate events, for they occurred on separate occasions.

However, the fact that events demonstrably occurred on separate occasions does not require that the cognitive system represent them as so. Would we be able to distinguish the two events? Close consideration does not reveal a method by which this could be done. It seems clear to me that we make judgments and represent events on the basis of their content and perhaps their qualities (i.e., distinguishing between the two because ISWOPPED is hazier than ISWOPPED2). And it is clear that events always differ in terms of their content, and context, even if the context is merely the knowledge that this is a reoccurrence of an identical event. But it seems false to claim that one could, without recourse to these factors, distinguish between two events. It seems false to even claim that someone could recall one event, and not the other.

I propose that in LTM (and, by extension, the autobiographical memory system which has its origins in LTM representations), we simply do not have access to a route which, irrespective of memorial content (and a knowledge base which allows us to make inference upon it), allows us to make temporal judgments about past events. The idea that two events that are remembered as identical could nonetheless feel distinct, separate from their affective, cognitive and spatio-visual content, is an alien one that does not accord with our own intuitions. The very fact that it is almost impossible to seriously consider real analogues of ISWOPPED and ISWOPPED2 is indicative of the fact that beyond the level of STM, memory offers us representation and metarepresentation that make redundant additional coding systems.

Having addressed the richness that characterises LTM, the next section will address the corresponding issue of whether it makes sense for specifically short-term memory to be underpinned by temporal information.

1.3.2 Time and STM: A special case?

In Section 1.1.4, I raised the idea that the abundance of evidence for clock processes operating over short time-scales, together with the paucity of evidence for clocks at longer time-scales, is consistent with demands of short-term processes. I argued that speech and motor actions both have dynamic components which demand of our cognitive systems a control over and on-line representation of temporal information. One implication of this is that it is important to be critical of attempts to assume biological clocks being involved in cognition over longer time-scales on the basis of parsimony: there are good reasons why temporal information is needed at short-time scales, which do not apply to longer periods.

This section shall extend this argument, and marry it with some experimental findings. Firstly, in describing the demands of speech production, I focused on the dynamics of individual items. Time and order are important in some further respects. It is essential for *prosody*, which is “modulations in speech melody (fundamental frequency, F0), amplitude, and duration”; prosody is the involvement of time “at a higher-order level that subsumes individual speech segments to form syllables, words, and sentences” (Shirmer, 2004, pg 270). Moreover, tasks depend as crucially on the order of events: /d/ must follow /o/ must follow /g/ to draw the correct meaning from the utterance. This means that short-term memory requires a parsing of the serial order of components which is accurate and absolute. Getting the gist, or registering key features (such as the fact that an unusual /kw/ sound was earlier than the other consonant, /t/) is not good enough. The argument that auditory systems are especially sensitive to temporal information is supported by findings that our ability to reproduce auditory rhythms is superior to that for visual rhythms (Glenberg & Jona, 1991).

It may even be that this sequential structure of speech was driven by its more basic dynamic qualities. Speech dynamics demanded on-line control over temporal properties of items, which was then exploited for orchestrating and maintaining the correct order of more complex utterances. This chain of involvement may have its origins in gesture, as some researchers have argued (Corballis, 1999); harnessing the dynamic control demanded by motoric action sequences. It is worth considering that deriving meaning from order is a useful but non-compulsory feature of speech; in principle, a combinatorial system could operate at the phoneme level as Latin did at the morpheme level — the presence of a set of unique units in any order determining meaning. Instead, language is composed of units produced in fixed order.

Sequencing is also a core component of other motor behaviour besides speech. Indeed, movement sequences can be considered to possess a syntax independent from their content, in a similar way to language (Lashley, 1951). Neurons have been isolated that are involved in the coding of serial order for natural movement sequences (Aldridge & Berridge, 1998) and the authors suggest that the underpinnings of sequencing behavior are “likely to be ancient and may have evolved originally to coordinate instinctive movement sequences.” (pg 2785).

Following this line of reasoning results in the following propositions:

1. That biological clocks involved in cognition developed in order to deal with problems of dynamic peculiar to speech and motor action over the short term
2. These processes were exploited by the STM system to solve a second problem: the sequential combination of items in speech and to a lesser extent motor actions, leading to access to temporal information for online-processing of items temporarily held in store.

This assumes, of course, that a timing signal is involved in STM. In either case, temporal information is especially needed in STM and access is relatively available to it. Meanwhile, LTM neither demands extensive temporal information nor has available to it a dedicated system that could supply it. It should not surprise to find temporal information available to STM processes, but their involvement in LTM is far less likely.

1.3.3 Evidence for a narrow STM role for timing signals

What evidence is there for these claims? Some recent papers seeking to articulate the role of timing signals in STM highlight the close relationship between evidence for timing and an involvement in speech specifically, or STM generally.

A timely recent paper (Hitch et al., 2005) draws attention to precisely these issues. Hitch et al. investigated transfer of serial order information from short-term memory trials to a serial learning process. Their results are in a similar vein to other recent work in undermining chaining accounts (fragments of a chain that do not maintain their relative position across lists do not lead to substantial serial learning) and providing some support for position coding (specifically start-sequence models). Hitch et al. also show evidence for additional higher-order information that

relates to the overall sequence. These findings lead them to “question our initial assumption that the serial ordering processes involved in short-term memory and serial learning are the same” (pg 257). If this is not the case, they conclude, “current models of serial order in STM will require qualitatively different mechanisms for the learning of serial order in LTM” (ibid).

Gupta (2005) suggests that verbal serial recall tasks are characterised by the same pattern of performance as tasks which involve listening to and repeating unfamiliar verbal items. This is taken as preliminary evidence that the same serial ordering mechanisms underly both tasks. This would be consistent with an account in which to allow the learning of novel words — where order of items is critical for maintaining meaning — serial order mechanisms arose which could then be employed by tasks such as serial recall that also demand the preservation of order information at this timescale.

Henson, Hartley, Burgess, Hitch, and Flude (2003) in a recent paper investigated the degree to which a timing signal may be involved in the serial ordering of STM. They do not offer a novel model but assess the contribution of a timing signal to explaining various effects using the list probe/item probe paradigm discussed in Section 1.2.1. They find “limited support” for the timing signal account, but their support is instructive in highlighting the peculiarities offered by STM serial order.

They highlight an unusual finding: that sounds impair serial recall tasks but not other memory tasks. When presented in parallel with a memory task, both irrelevant speech (Salamé & Baddeley, 1982, 1990) and simple tones that change in some way (D. M. Jones & Macken, 1993, 1995) impair serial recall performance, but leave performance on an equivalent non-order task (in the former case, free recall and in the latter, performance in a missing item task) unaffected. This is consistent with the idea that order in STM is tied to phonological processing. They also present a suggestion made by N. Burgess and Hitch (1999) that rhythmic production tasks such as finger tapping might draw on the timing resources upon which the STM timing signal depends. Evidence to support this comes from involvement of the brain region identified as involved in rhythmic motor regions (Catalan, Honda, Weeks, Cohen, & Hallett, 1998) in the maintenance of sequential order in STM (Henson, Burgess, & Frith, 2000).

Henson et al. confirm and draw out these phenomena in their experiments. Finger tapping leads to impaired performance on the List Probe (LP) task which requires retention of serial order information to a greater degree than on the Item Probe (IP) task which merely requires recognition. Their prediction of greater disruption from more complex tapping rhythms was not born out,

which they argue counts against the two processes competing for a common resource. However, it is consistent with effortful controlled motor action (regardless of complexity) requiring a divestment of the timing system from inessential (i.e. non-motoric and non-speech) tasks. Similarly, irrelevant speech, although not appearing to interfere with subvocal rehearsal (unlike the articulatory suppression condition involved in Experiment 2 of the study), had a disproportionate detrimental effect upon LP relative to IP.

Henson et al. weigh other explanations for their findings, such as the disruption of associative links between items, but the crucial issue is this: to the extent that there is evidence for a time-code, it is consistent with the argument advanced above. Specifically, the timing signal is underpinned by mechanisms that arose to deal with problems of a particularly short-term nature, dealing with motoric and speech production, and developed within that framework. Transient timing information is available to deal with on-line, short-term speech processing, or motor and speech production. This implies that the long-term, episodic memory system could only be organised in a chronological manner if it arose later than speech, and demanded with sufficient urgency (i.e., placed a sufficiently high selection pressure on its prioritisation) that a system developed to deal with dynamics over the second be expanded to deal with the order of events over days, developing a way to make temporal information be permanently associated with individual memories. Given the rich resources available to LTM, this seems implausible.

1.3.4 Lessons for LTM

It is convenient to draw on findings and models from the STM literature in attempting to understand LT episodic memory. STM is heavily researched, using paradigms which are well-controlled and data-rich to deliver robust findings and encourage exacting computational models. However, there are good reasons to be wary of this approach. Memory researchers currently consider there to be clear blue water between STM and LTM. Tulving, one of the “godfathers” of the concept of episodic memory, articulates this distinction in a recent book:

“in traditional thought, as in common sense, memory is ‘unitary’ in the sense that there is only one ‘kind’ of memory, as there is only one kind of water, or blood or forget-me-nots....Today, the break between primary memory, or its more theoretically meaningful successor, ‘working memory’ (Baddeley & Hitch 1974), on the one hand,

and secondary memory ('long-term memory') on the other, is as sharp as one can find anywhere in nature" (Tulving, 2001, pg 270).

I have given an account for why we care must be taken in generalising across these two domains in the case of temporal memory. Timing information may have been both available to and necessary for the STM processes involved in speech and motor behaviour, but unavailable and unnecessary for the kinds of order demands made by LTM.

As I have reported, Conway has argued for a further divide between episodic memory, essentially sensory-perceptual and experience-near, and autobiographical memory. Caution should be applied when trying to draw fundamental principles from one domain over the other. However, this does not prohibit us from examining concepts and strategies at one timescale in order to assess their explanatory utility. Similar mechanisms can arise independently if there is an adaptive reason for their use in both situations, analagous to homoplasy (adaptive features in different species not accountable to a common ancestor, e.g., Wake, 1991) in evolution. The philosopher Dennett discusses the concept of *good tricks*, where the "obvious excellence" of a strategy leads to its adoption in independent circumstances (Dennett, 1995). Some of the aspects of autobiographical memory may be good tricks, and the tasks that LTM deals with may be similar enough that one could expect to see the re-use of these good tricks. One candidate for a good trick is the temporal landmark.

Temporal landmarks in LTM

In Section 1.2.5, I addressed the concept of the temporal landmark in autobiographical memory, and how its use as a sorting strategy was both useful and ubiquitous. The use of temporal landmarks may be one aspect of the way in which temporal judgments are made in LTM. A strength of including temporal landmarks in an account of temporal order memory is that it does not assume anything beyond standard memory processes. A temporal landmark must be associated with an item, either by links of varying strength (with closer items linked more strongly) or by a semantic relation coupling the two together (such as "right at the start", "second from the start", "third/near the start" until the links are no longer useful). Unlike time-code models, it does not require any auxillary processes or the channeling of information from other systems. It effectively requires an extension of chaining accounts of item-item associations to include temporal landmark-item associations. In this I follow Yonelinas when he argues "Do we need more than a single type of

memory or process to account for recognition memory performance? If it is possible to account for performance with a model that involves only a single type of memory then this simpler model should be preferred.” (Yonelinas, 2002, pg 441-2).

In fact, several of the order-memory accounts can be recast in terms of two memory components—familiarity and recollection. For example, under the Mandler model (see e.g., Mandler, 1991), familiarity is the level of item activation due to its study, the level of which can be used to assess its status (seen/not seen). This has close correspondence with the distance accounts of order memory, discussed in Section 1.2.2 where items are assessed as more/less recent on the basis of some memory quality, such as trace strength vividness or generalised strength. Accompanying familiarity is recollection which is a search process that allows access to more elaborate item content and additionally interitem information. This can be seen as analogous to the chaining approach, where items are linked to one another by associations that determine their order, and additionally the landmark approach, where items are linked to a temporal landmark or some other marker of context in order to confer temporal information. Under such a framework, it may be possible to explain much of the characteristics of LTM order memory, without recourse to the *deus ex machina* of temporal coding, which I have argued is, like the origins of the term, an improbable turn of events.

There are two ways in which landmarks could be used. Firstly, there are those that are significant in their own sense: for example a hunting foray. For a social animal, such a situation has functional and social consequences: it has an associated risk, brings with it an increase of resources, and requires monitoring of effort and involvement in order to assess merit and motive of conspecifics. Remembering who did you a favour before the pay-off allows you to rewarding the patient rather than the fairweather friends. This is an essential prerequisite to developing evolutionarily stable strategies for reciprocal behaviour (Axelrod & Hamilton, 1984)

Another way in which temporal landmarks may be involved in LTM is in coding the boundaries of discrete periods. Such boundaries confer useful information: whether an event falls in or outside of a certain context, for example. The primacy and recency effects observed in LTM list-based order paradigms could be considered as evidence for this, an argument advanced by Friedman (2001), who cites a number of studies demonstrating primacy-recency effects in LTM. Recency effects can be interpreted in a number of different ways: the decay function of qualities used as proxies for temporal distance, the ratio rule, the retention of items in working/short-term memory. Primacy, however, is open to fewer interpretations, and cannot be explained by recourse to basic

temporal information (the beginning of a list is not meaningful in a abstract temporal sense, only meaningful in a contextual sense).

It should also be noted that intuitively, it is less clear how events can be coded with respect to an event that has not occurred, such as the end of the list. In principle, this information could be appended by some sort of post-hoc mechanism, but this seems more implausible than in the case of list start, where subsequent items can be encoded as “right at the start”, “second from the start”, “third/near the start” with diminishing utility. This also would also negate one of the attractive features of the landmark account, its dependence only on known and well-established memory features. This parallels the finding in autobiographical research that first events tend to make good landmarks: beginnings convey useful temporal information. Typically, then, primacy fits poorly with many other accounts but well with temporal landmark accounts, whereas recency fits well with other accounts (including time-code accounts) but slightly less well with temporal landmark explanations.

My interest in the application of temporal landmarks has led me to investigate more closely the primacy and recency effects, in order to assess whether they fit a landmark account, a temporal code account, or alternatively a positional account, the strongest candidate being the SEM (Henson, 1998b). Previous research on these effects in LTM (e.g., the examples cited by Friedman), is not new, and was not conducted with an interest in assessing landmarks or the more modern candidates I am considering.

1.4 Overview of Thesis

In the preceding sections, I have argued that current attempts to see order memory as the result of time-codes derived from biological clock systems, intuitive though they may seem, fail to recognise the special circumstances that may have allowed timing mechanisms to arise over short term periods, and overstate the need for highly-veridical order information in LTM. Approaches that attempt to account for LTM temporal order via an existing memory framework are preferable when the evidence is equivocal. I have also argued that the balance of evidence for autobiographical memory similarly tilts against an account of chronological organisation or temporal tagging, and touched upon issues where neuropsychological evidence can aid in distinguishing between accounts. I will now summarise the experimental aims of this thesis.

1.4.1 Investigating LTM memory

The LTM research has not in the main directly addressed some of the more recent models which could account for temporal order memory. In particular, models that invoke temporal oscillators (popular in recent STM research) and models that draw on temporal landmarks (typically found in autobiographical memory research) are not assessed, and their plausibility tends to be examined by reliance on antecedent studies.

In the next chapter, I wish to more directly test some of the implications of the SIMPLE model, which claims all memory is chronologically organised. A cardinal feature of SIMPLE is the ratio-rule, by which for any pair of events the ratio of temporal distances to the present determines the ease with which they can be distinguished. To what extent does the ratio-rule characterise temporal order judgments in LTM? Beginning with an exploratory study (Experiment 1) seeking to characterise primacy and recency effects in LTM, Chapter 2 addresses this question, demonstrating a poor fit between predictions based on the ratio rule and data. Experiment 2 examines the fine-grained predictions the ratio rule produces regarding recency and the benefit of recent items to being tested immediately rather than following a delay. Additionally, the extent to which the SEM can characterise the pattern of performance in LTM is addressed, with Experiment 1 suggesting that the model fails to capture performance at this time-scale, and Experiment 3 examining its performance under a manipulation that might be expected (by both Henson and other researchers, e.g., Tzeng, Lee, & Wetzel, 1979) to allow better conditions for dual-coding.

Following this, Chapter 3 pursues an alternative perspective, one which characterises the primacy effect as the consequence of the start of list being a useful temporal landmark. It investigates whether rehearsal (Experiment 4) or absence of proactive interference (Experiment 5) may present plausible alternative explanations of primacy, and tries to assess the extent to which the primacy effect is the consequence of volitional, strategic processes (Experiment 6).

Throughout these experiments I will be using the judgment of recency. The serial recall task is an appropriate task for tapping the ability to sequence a number of immediately consecutive events that must maintain their order to produce the same function, such as speech and motor production. In understanding our ability to temporally order our past, over long time periods, the task becomes extremely unwieldy. It does not have correspondence to the kinds of temporal judgments made in LTM. The list probe is an interesting new technique but, similar to serial recall, does not correspond to natural events; in any case its use has only entered the literature

since the commencement of this thesis. Item sequencing is possible in LTM but is again artificial and involves the sustained simultaneous re-presentation of studied items, which risks interfering with item-item associations, item-landmark associations, and other factors which may be of crucial interest. Now/past recognition suffers from the fact that it is unable to assess the ability to make relative judgments of past events, simply a distinction between now and the past. Schnider (2000) has argued that this ability is a distinct one from temporal judgments, and involves the association of “currently relevant” information with motivational markers (as distinct from temporal ones). Given this prospect, it seems unwise to conflate the two issues by using these types of tasks.

The JOR, on the other hand, has correspondence to real-life situations, such as judging whether a food cache has been more recently replenished or raided, and in inferring the causality between events. It is relatively simple and can be applied easily in LTM lists. It has been criticised recently, on the basis that it could in principle be performed on the basis of “relative levels of item strength in memory” Henson et al. (2003, p1309). Given that the JOR mirrors the kind of behaviour I am interested in, and the fact that item strength is a legitimate theory of temporal memory, this begs the question.

1.4.2 Investigating autobiographical memory

Chapter 4 turns from LTM to autobiographical memory, in order to pursue two of the issues discussed here. Firstly, in Experiment 7, I examine the involvement of dedicated temporal information. For time-code information to be scale-invariant, as argued by G. D. A. Brown, autobiographical memory must have access to this information. It may be that other information is also used, but for the claim to have any substance it must offer some benefit. One would expect, for example, that possessing a time-coded memory for an event — as opposed to hearing about it second-hand, after the fact — should necessarily result in better accuracy in temporal judgments about it. This is tested using a public events task completed by two different age groups: an older adults group who lived through events, and a young adults group who were juvenile or unborn across events. The evidence suggests that whereas young adults appear to make judgments based upon the internal content of the event, older adults do not rely on this information, nor do they exhibit better performance on the basis of additive dedicated information.

The second issue, addressed in Experiment 8, concerns the types of information that do inform temporal judgments about events that have been lived through. The role of temporal landmarks

are well-established in autobiographical memory; and this experiment seeks instead to quantify the involvement of temporal information from another level of organisation in autobiographical memory, that of life periods. The evidence suggests that internal content, tapped using multiple measures, is not relied on, whereas the external context, in terms of life periods, does distinguish correctly and falsely dated events.

1.4.3 Neuropsychological investigation of temporal memory

For the purposes of this thesis a case series of neurological patients has been recruited in order to address some key issues using neuropsychological techniques. Chapter 5 presents some preliminary findings from a number of investigations.

Experiment 9 continues the use of the JOR to look at the issue of dedicated temporal information from a viewpoint common to neuropsychology: are temporal context deficits special, or just the consequence of poor context memory, or poor memory in general? It also addresses a methodological issue: are some tests of temporal memory open to artefact when employed on memory-impaired patients? The current data reflects the pattern found in the literature of poor frontal performance on temporal (e.g., Kesner, Hopkins, & Fineman, 1994) and poor amnesic performance on spatial context tasks (e.g., Smith & Milner, 1981), but shows a blurring of this distinction consistent with more recent research (e.g., Kopelman, Stanhope, & Kingsley, 1997). It suggests that contextual deficits may commonly co-occur and present across aetiology.

One direct prediction of time-code accounts of temporal memory is that these impairments of timing and temporal memory should co-occur. In Experiment 10 a direct comparison between performance on these two tasks is examined, and little evidence can be found for a relationship. Specific evidence for preserved timing ability in the face of temporal memory impairments is presented, which does not support time-code accounts, but is neither a compelling rejection of them.

2. THE JUDGMENT OF RECENCY PARADIGM AND ORDER REPRESENTATION

This chapter looks at a particular kind of temporal memory judgment, the judgment of recency (JOR), on items in LTM. A JOR requires one to specify which of two events happened more recently, often after encountering them as part of a serially presented list. It is this that underlies the ability to know whether a food cache was more recently visited to make a withdrawal or deposit, and consequently whether it is full or empty (Clayton et al., 2003), or to assess the causality of two events, and so infer facts both about the physical world and the social environment (McCormack & Hoerl, in press). This type of task corresponds to real world demands, both of the present and our evolutionary past, and hence is preferable to the more prominent paradigm of serial recall. The latter, in which a list of items presented must be reproduced in the corresponding order, is a data rich technique that allows extensive modelling, which may explain the long pedigree of research upon it (see e.g. Neath, 1998). However its use as a tool to investigate temporal memory suffers from the many factors beyond memory for order that seem necessarily involved (Cowan, Saults, Elliott, & Moreno, 2002). To attempt to untangle these can lead to task demands that are ever more complex, such as beginning serial recall from part-way into the list and cycling around to the start of the list, for example being required to recall items 1–9 in the order 5, 6, 7, 8, 9, 1, 2, 3, 4 (Healy, Fendrich, Cunningham, & Till, 1987). Another alternative, free recall, has been used to indirectly suggest that temporal context forms a cue that assists memory retrieval, on the basis of recency effects within the data (Glenberg & Fernandez, 1988). However, as a measure of order memory this technique does not provide us with direct information

Studies that employ the JOR, although having a more complex basic design owing to the fact there are always two factors in question (the recency of each of the two items), tap only the ability I am interested in: telling which of two cued memories are of a more recent event. A use of a blocked-design paradigm also provides the ability to examine primacy and recency effects within the data. Such a paradigm is employed here to shed some light on various aspects of temporal memory.

This chapter begins with Experiment 1 which pilots this paradigm in an explorative study that investigates the role of two positional factors, rate of presentation and modality in JORs. Its findings have implications for the temporal discrimination models of G. D. A. Brown and colleagues (G. D. A. Brown & Chater, 2001) which are examined more closely in Experiment 2. Experiment 1 also poses problems for the extension of end-coding models into LTM, leading to Experiment 3 in which the paradigm is modified to assess these implications.

Experiment 1 — Positional, Modality and Temporal Effects within the JOR Paradigm

Absolute Position: Item proximity to a terminus

Previous research has shown that several types of memory judgment are better when they involve items close to the beginning or end of a list. There is much research on the superior recall of start and end items in lists in short and long term memory (e.g. Hultsch & Todt, 1996; Murdock, 1962; Paul & Whissell, 1992) which are often characterised as primacy and recency effects. Early work sought to harness these as evidence for two types of memory store (Peterson & Peterson, 1959; Waugh & Norman, 1965), but resistance to this (see Baddeley & Hitch, 1993) has led to attempts to explain the effects within unitary models of memory. One example is the Start-End Model (SEM) proposed by Henson (1998b) to account for human performance at short term memory sequencing tasks. His model proposes that we are able to reproduce items serially as a result of encoding positional information with each item. In this model, item coding is achieved using a bi-vector feature system (x,y), the vectors coding proximity of the item to the start and end respectively of the sequence it resides in. Items near the start have a distinctive code — a very high start coding coupled with a very low end coding (approaching 1,0) — as do those near the end (in this case approaching 0,1), whereas items towards the middle of a sequence possess codes that are less distinctive.

The SEM accurately models many of the phenomena exhibited in within-span serial recall, but whether these findings might extend into LTM has not been fully explored. Serial recall has been shown to be better at extreme positions (e.g. Hintzman & Block, 1971; Toggia & Kimble, 1976). Primacy and recency has been demonstrated in JOR paradigms where study and test are interleaved such that recency is not the end of the list but any instance in which a study item is

immediately followed by a test trial probing accuracy for that item (Fozard, 1970; Wolff, 1966; Yntema & Trask, 1963). Primacy effects have been documented in blocked study-test paradigms (Tzeng et al., 1979), but it is necessary to establish whether recency can also be demonstrated, and how it relates to other factors. Is order memory better for items previously encountered near the terminus of a studied list — and do these termini have equivalent effects? Recent work within the serial recall literature argues that the primacy effect documented there may be largely a product of output interference effects (being recalled first) and response size effects (Cowan et al., 2002), and that recency effects may be a larger factor in order judgments than has been traditionally considered in this literature. Against this, the SEM proposes that proximity to either termini should have broadly comparable effects. There are also reasons to believe that the end of a list may be a less useful temporal landmark to code items against in long term memory, as opposed to the rapid lists involved in serial recall.

Coding against a prospective event may be plausible for sequences of five or six items spanning a few seconds (Henson, 1998b), but it is unclear that this approach would benefit the final items in a list presented over several minutes or more. This may produce a noisy vector, or rule out end-coding altogether. In this case, a positional account might suggest that judgments within-list must be made using a single positional code (Conrad, 1965; Lee & Estes, 1977) although position across lists might involve additional codes, see Lee & Estes, 1981). An alternative possibility is the temporal discriminability approach of G. D. A. Brown and colleagues (G. D. A. Brown & Chater, 2001; G. D. A. Brown et al., 2000). These predict a graded recency effect, as judgments involve comparing the time elapsed since the encoding of each judged item, such that larger ratios lead to higher accuracy, and two items of fixed lag will derive their highest ratio when judged soonest.

In addition to the rationales presented from previous list-learning studies and short-term models, long-term memory research offers a reconstructive approach (e.g. Friedman, 1993) wherein contextual information forms the basis for temporal judgments. As a consequence temporal landmarks, such as list beginning, prove a useful context that improves accuracy. Such models would predict a facilitative effect only insofar as the landmark was effective — like a conventional landmark, it must be identifiable at coding and reconstructed at retrieval. As such, list end may prove to be a less useful landmark, being less tangible at the point of encoding, and so produce less benefit for accuracy. The present study will investigate whether an effect for pairs involving terminal items differs depending on whether items are from list start or list end.

Relative position: Separation due to intervening items

Recency judgments may also be affected by whether the items being judged were presented close together within a list, with few items intervening, or widely separated, with many items intervening. Positional models such as the SEM predict that separation due to intervening items should produce enhanced order discrimination, due to more distinctive coding for more distant positions. The same prediction is made by compound chaining models (e.g. Elman, 1990); these propose that items are encoded together with contextual information about surrounding items, with more contextual information contributed by immediate neighbours and increasingly less as the items become more remote from one another. Such models would predict that if a sequence of items A,B,C,D,E to J were presented serially, Items B and D would be hard to distinguish temporally because the contextual information afforded to both included a lot of information from Item C, albeit with some differential in the amount of information from items A and E. Both these and positional models lead to the prediction that recency discrimination should be easier when items are, say, ten positions apart rather than five apart.

In contrast, simple chaining models of short term serial recall, (e.g. Wickelgren, 1965) suggest we perform order judgments by following chains of associations from item to item; this predicts that more separated items would in fact be harder to make recency judgments upon. Tzeng and Cotton (1980), whilst not making strong predictions about relative position, does not offer explanation for relative position effects. Previous evidence (Fozard, 1970; Tzeng & Cotton, 1980; Toggia & Kimble, 1976; Yntema & Trask, 1963) supports the first set of theories, in that separation does appear to lead to greater accuracy of judgments. However, a number of these use the interleaved study-test paradigm, and that which does not, Tzeng and Cotton's investigation of categorisation, does not report whether it used a matching procedure to disentangle relative and absolute position. It additionally prevented assessment of any possible interaction between the two positional effects, by omitting primacy and recency items from analysis. The effect of widely-separated versus near-separated judgment pairs will be investigated within this study using a matching procedure to assess its contribution outside of confounding factors. Moreover, possible interactions between the two positional effects of absolute (proximity to start or end of list) and relative (pair separation) position will also be examined.

Stimulus type or modality

A further manipulation this study will employ is that of modality of the studied items. The use of different modalities allows us to assess the generalisability of the positional effects being investigated. If an absolute positional effect (e.g. enhanced performance for JOR pairs containing an item from the end of the list) is found for verbal material, it is valuable to know whether this is modality-specific, or a more general property — that is, general at least to items learned in lists.

Moreover, the use of multiple modalities allows the investigation of modality effects in temporal memory. A modality effect in memory performance is found across a variety of domains and task requirements, often using pictures versus verbal material (Conrad & Hull, 1968; McAndrews & Milner, 1991; Paivio, Rogers, & Smythe, 1968). A rationale for the effect is that two representations are formed for pictorial stimuli (non-verbal visual and an additional verbal representation which is created via an automatic labelling process) which contribute information in an additive manner (Paivio, 1991). Although an effect of picture superiority over verbal stimuli in recall is a common finding (Paivio, Rogers, & Smythe, 1968), there is less work on whether this generalises to recency judgments.

Also to be investigated is the effect of enactment of actions sequences upon JOR performance. Nilsson and Cohen (1988) detail the benefits to learning accrued by enactment of items rather than passive presentation. McAndrews and Milner (1991) investigated this effect in a neuropsychological study of order judgments in frontal patients using a similar paradigm. The impairment these patients exhibited relative to a control group at recency tasks was reduced when they performed the action in addition to reading its description. Such evidence is consistent with the dual-coding hypothesis that a richer memory representation is formed for each item, and the fact that this facilitates temporal discrimination between items implies that item-specific information is used by the JOR process, and that the JOR decision is not based solely on temporal or positional information. Increasing the amount of information available about an item by allowing it to be encoded with multiple representations, or in some sense a richer representation, makes it more discriminable.

However, the evidence from enacted items can also be interpreted under an alternate hypothesis, that motor sequences encourage the involvement of systems that store order information. Chapter 1 (Sections 1.1.5 and 1.3.2) presented a case for greater need for dynamic information for certain kinds of short-term behaviour, namely speech and motor production. Superior JOR performance

for action sequences may suggest that order information (possibly from a dynamic oscillator system, or some other system dedicated to preserving action syntax) is available to motor sequences beyond the short-term level.

This experiment consequently examines whether modality effects may be found in both visual stimuli that has a readily available verbal label, and enacted motor stimuli, relative to purely lexical stimuli. Should both pictures and actions show better performance, this would be consistent with a dual-coding modality effect, where the advantage of actions may be seen as the consequence of multiple routes of coding the presented information. However, if actions lead to better performance than pictures, this is more consistent with a privileged role for order information about motor sequences.

Presentation rate

Finally, to allow further assessment of generalisability claims, and to allow a preliminary investigation of the sensitivity of JOR performance to rate of presentation, participants will be provided with study lists at one of two presentation rates. It may be, as argued by some models of order memory, that time per se is crucial to our ability to order events. This may be via the use of a dedicated time code (G. D. A. Brown & Chater, 2001) or the use of some proxy measure such as trace strength (Hinrichs, 1970). If, on the other hand, positional relationships or contextual factors are the determinants of order memory, temporal manipulations should not have an effect.

A Method to disentangle relative position and study absolute position in judgments of recency

This experiment uses a task in which items were presented in a serial study list, after which the participant completed a number of judgment-of-recency (JOR) trials, in which the task is to identify which of two re-presented items was more recently seen within the study list. I am interested in how the position of items in a JOR pair relative to one another, and with respect to their position in the list, affect how accurately they are then ordered. These two variables of interest, absolute item position and inter-item separation, present a challenge in that one partially determines the other. A pair of items to be judged composed of items five and ten from a list differs from a pair composed of items five and fifteen in two ways — the distance between the items and the position of one of the items. Consequently there is a problem in disentangling these confounding variables that



Fig. 2.1: Composition of 10-distance pairs.

this study aims to solve using a particular design. Another issue for investigation is whether effects are generalisable across modalities, and additionally if there is a benefit to performing judgments about items that may be more richly encoded through their modality. A design was employed that would allow fruitful investigation of all these issues, and requires a little explanation.

One study issue is the effect of relative position when certain control measures are employed. Guided by Tzeng and Cotton's (1980) long-term memory JOR study, where participants showed better performance when inter-item distance was 10–19 positions over 0–9 positions, the two levels of separation selected are pairs of distance ten versus pairs of distance five. To satisfy these criteria a study list of twenty items would be suitable, as it allows us to produce ten 10-length trial pairs with no redundancy of items, as seen in Figure 2.1.

The use of a study list of twenty items is also well suited to consider separately the role of Start/End Items. Tzeng and Cotton's (1980) study treated the first and last five items within the list as the primacy and recency items, that is, those expected to provide a boost to performance on the basis of their absolute position. On this basis, the pairs produced in Figure 2.1 can be divided into two — those pairs containing start items (1–11, 2–12, 3–13, 4–15, 5–15) and those pairs containing end items (6–16, 7–17, 8–18, 9–19, 10–20). The use of twenty item lists allows us to derive three types of pairs: Start pairs, End pairs, and additionally Middle pairs, containing neither primacy nor recency items. This are illustrated in Figure1. As can be seen, using a twenty item list, all three categories would contain five pairs. This will allow the comparison of Start and End item performance against one another, and additionally provide a baseline against which to establish whether primacy and recency effects are present in this paradigm. Each study phase is consequently composed of the presentation of a twenty-item study list, in one of three modalities — this allows us to measure modality effects in the recency judgments participants make at test. These modalities comprise verbal items, concrete pictorial items, and verbal items with a required action component.

Each study list is followed by a test phase, in which test pairs of items drawn from the previous

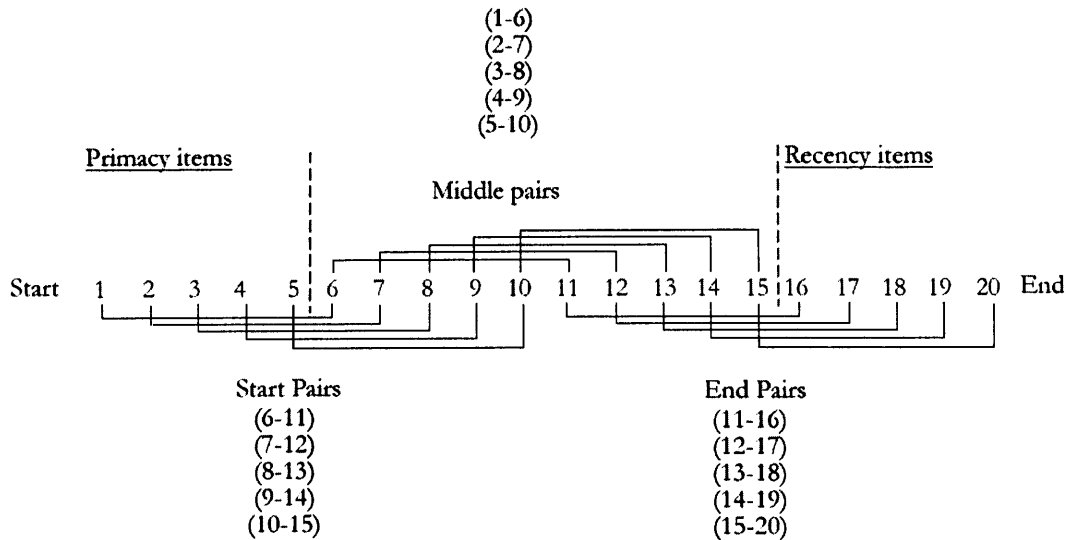


Fig. 2.2: Item membership for Start, Middle and End Pairs at 5 separation.

list (and consequently of the same modality) are presented. The identity of these test pairs will depend upon the current test condition. Under each modality every test condition will be experienced once, so allowing us to also investigate interactions between modality and positional effects. Figure 2.1 illustrates the members of one test condition, allowing us to measure performance when items are well-separated. To make a comparison, the opposing condition must be composed of items from Figure 2.2. However, Figure 2.2 is composed of fifteen item pairs, whereas Figure 2.1 only ten. Which ten item pairs are appropriate to compare? This is in fact, the problem that this study hopes to disentangle. To choose the first ten pairs, which are matched for the early item, does not allow us to attribute any difference in performance to relative separation, as the effect may be liable to the position of the later, target item. A complementary criticism exists for the opposite solution of selecting the later ten pairs. However, if the 10-length test condition is matched against not one, but two 5-length conditions, one composed of the first ten pairs from Figure 2.2 and one of its last ten pairs, then this issue can be overcome. Should the 10-length condition outperform (or underperform) one, but not the other of the matched conditions, then this is not a confident endorsement of a relative position effect.

Should it prove inferior or superior to both, then this allows a claim to be made with some confidence that this demonstrates an effect that is neither attributable to the status of distractor alone nor target alone, but rather the relationship between the two of them; this state of affairs poses a strong case for a relational, positional effect. Table 2.1 shows this. Column i is compared

separately against Column *ii* and against Column *iii*.

Tab. 2.1: Breakdown of comparison groups for assessing pair separation.

10-Length	Distractor matched	Target matched
1-11	1-6	6-11
2-12	2-7	7-12
3-13	3-8	8-13
4-14	4-9	9-14
5-15	5-10	10-15
6-16	6-11	11-16
7-17	7-12	12-17
8-18	8-13	13-18
9-19	9-14	14-19
10-20	10-15	15-20
<i>i</i>	<i>ii</i>	<i>iii</i>

These design requirements determine the structure of this study. The experiment uses three modalities of study list; for each modality of study list, there are three runs — under one the test phase will be composed of Figure 2.1i, another Figure 2.1ii, and a further Figure 2.1iii. Through these test phases each participant will be tested using Start and End pairs with 10-length, and Start and Middle and End pairs of 5-length. The data this supplies can be recategorised to allow us to make the comparisons of interest: between Start, Middle and End (using only the 5-length pairs), and between Start and End at two levels of relative position (by comparing the data from Start and End pairs at 10-length and 5-length in a derived 2 X 2 design). These comparisons fall directly from this structure. Nine study lists of twenty items, each list followed by a test phase of ten judgments, does not constitute an extremely lengthy or fatiguing experimental design, and so allows the employment of within-subject comparison rather than allocation of participants to distinct conditions.

Method

Materials and Participants.

This experiment was run as an executable program written on Visual Basic, in which twenty-item lists are presented under different modalities: three lists of words, three lists of pictures and three lists of actions. The words are concrete nouns of similar frequency and saliency (e.g. blanket, cake, folder). The pictures are line drawings taken primarily from Snodgrass and Vanderwart (1980). The actions are simple motor actions that could be produced immediately, (e.g. pout lips,

salute, rub your stomach). Lists are composed afresh for each participant by randomly drawing without replacement sixty items from a pool of ninety — the same set of stimuli is used for another study which requires these extra items. Each item in the pool can fall at equal probability in any position in any list, or be unused; consequently list position and the content of that position were independent. Physical materials were required for the study phases that involved actions. These were: a coin, a cup, a pencil and a ball. These were supplied beside the computer on which the task was run. All responses were made via a mouse.

Each test phase is composed of 10 trials wherein two words from the immediately previous list are presented to the participant who must choose the more recent. Information for each trial including the modality, original list positions of the word pair items, trial score (0 or 1) and latency times is recorded into a text file.

A total of 54 participants between 19 and 54 years of age participated in the study. They were composed of students recruited from the psychology department and additional participants who had been involved in previous experiments at the department. Eighteen participants performed the experiment under the fast presentation condition, whereas 36 performed under the slow presentation condition (18 participants recruited alongside those in the fast presentation condition, with an additional 18 from an earlier testing session).

Design.

This study used a 3X3X2 (modality x test pair positions x presentation speed) mixed design. The two within-subjects independent variables were modality of study list and trial items (words, pictures or actions) and test pair positions (three test conditions outlined below). The between subjects variable was presentation speed of each item (slow, being 5 seconds per item or fast, being 2.5 seconds per item). The limited stimuli afforded by some modalities and a desire to avoid fatigue effects meant that the presentation speed was varied between participants rather than within.

Each study phase involves presentation of a list of items and is followed by a test phase in which participants are asked to make judgments of recency (JORs) between pairs taken from the prior list. The designs of study and test phases are outlined below. The design is common to both the fast and slow presentation groups.

Study phase. Each study phase involves the serial presentation of twenty items within a given modality: verbal (words), non-verbal visual (pictures) or verbal with a motor component (actions). The experiment is composed of nine study phases, and list modality changed between phases, progressing from word-picture-action. Each study list is followed by a test phase where pairs of items taken from the just presented study list.

Test phase. Each test phase is composed of 10 trials, each of which require participants to select which item from a pair presented on screen was more recently seen in the previous study phase. Trial items are taken from specific positions in the prior study phases, which are determined by the test condition. To summarise, 10-length condition involves items that were ten positions apart in the original list (e.g. 5th and 15th items), with target items consequently running from 11th to 20th (last) position in the study list. Distractor-matched involves items five positions apart (e.g. 5th and 10th position), in that its target items are five positions less recent than 10-length condition (6th to 15th position). The pairs for Target-matched are also composed of items five positions apart, but these are matched to the 10-length condition with respect to target items; instead the lure items (less recent) are fed forward to more recent positions. These are presented in Figure 2.1.

The same test condition is applied for three test phases, allowing it to be applied to each modality of item, and then changes. The order that the test conditions were presented for each participant was counterbalanced such that each condition was presented first, second or last an equal number of times.

Procedure

Participants were briefed on the general content of the experiment and then seated. The experiment was presented via a monitor using a standard personal computer. On-screen instructions directed them to watch the screen carefully and try to remember the content and the order of stimuli presented there.

Participants then initiated the study phase, wherein one of nine study lists composed of twenty items was presented serially. Each item was presented for a fixed presentation time, which varied between participants, with short presentation times at 2500ms and long presentation times at 5000ms. Items were separated by an inter-item spacing of 1000ms during which no stimulus

was shown. No behaviour apart from attention on the stimuli was required for the word and picture stimuli; the lists of actions required participants to physically perform the action that was presented as a statement on screen (e.g. fold your arms). A number of these actions involved the use of physical materials, such as a penny to pick up.

Once the study list had been presented, participants were informed they would now be required to make a number of relative recency judgments on items from the previous list. Participants then initiated the test phase containing ten test trials: for each trial, two items from the previous study list were presented in the screen, one in the upper half and the other the lower half of the screen. Participants made their choice by clicking on the button by the item that was judged to be more recent. The composition of the test pairs was dependent on the test condition that was running, as described, and the ten test pairs were presented in a fully randomised order. The target (more recent item) was the topmost item for half of the trials in each test phase, and the bottommost for the remainder. Following each test phase, the participant was instructed to prepare for another study list that would differ in modality (modality cycled from word to picture to action and back to word). After participating in word, picture and action blocks under one test condition a participant would participate in three equivalent blocks under the next one. After nine study lists had been presented and nine test phases under three different conditions performed, the experiment ended.

Data. The data was sorted into bins as appropriate, including high, medium and low pairs for certain analyses. The membership of these sets is outlined in Table 2.2.

Tab. 2.2: Group Membership of Data from Judgment Pairs Following Recategorisation into Start-short, Start-long, Start-middle, End-short, and End-long Groups.

Start-short	Start-long	Middle-short	End-short	End-long
1-6	1-11	6-11	11-16	6-16
2-7	2-12	7-12	12-17	7-17
3-8	3-13	8-13	13-18	8-18
4-9	4-14	9-14	14-19	9-19
5-10	5-15	10-15	15-20	10-20

Results

The dependent variables in this study were accuracy scores produced from judgments for each test trial, representing whether participants correctly chose from a pair of items the item that was most recently seen in the previous list. Accuracy on individual trials (ninety from nine blocks) was then

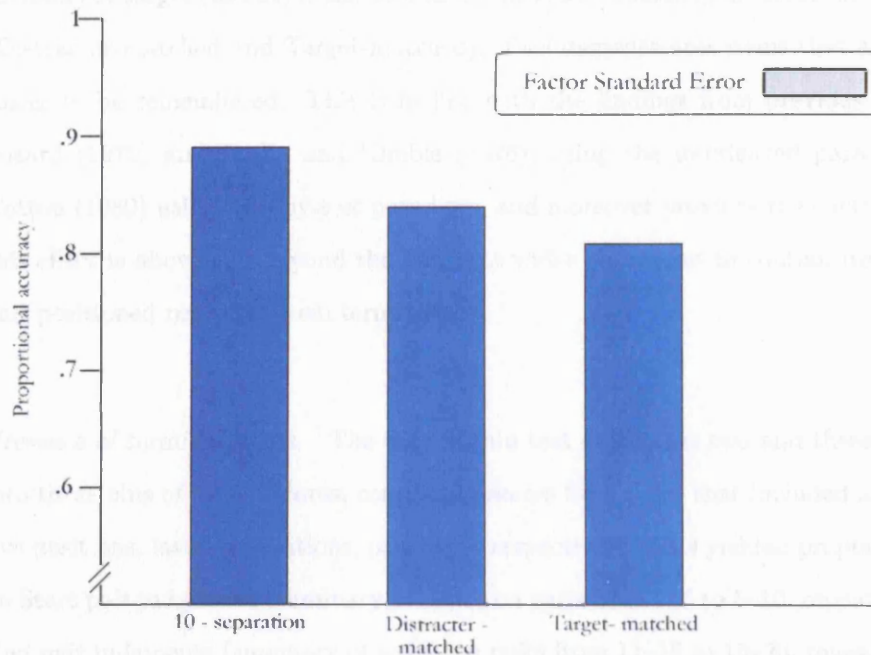


Fig. 2.3: Performance at separation 10 versus matched conditions. Error bars denote standard errors, as with all subsequent figures.

sorted into bins to allow various comparisons. These will be presented separately. An alpha level of .05 was used for all statistical tests in this experiment and thereafter unless otherwise specified. Brackets following mean scores present standard deviations unless otherwise specified.

Item separation. Across the three conditions, participants did best in the 10-length condition where item separation was ten, achieving proportional accuracy scores of .892 (.10) from the thirty trials across the three modalities. Performance was intermediate in the Distracter-matched condition where item separation was five and items tended towards the list start, scoring .84 (.118), and worst with a score of .809 (.120) in Target-matched condition where separation was five and items tended towards the list end. Figure 1 shows this graphically. Error bars denote standard errors, and this shall be the case throughout the chapter and subsequent chapters. An ANOVA conducted across these groups revealed a significant main effect of test condition: $F(2,106) = 12.144$, $p < .001$. Pairwise comparisons employing Bonferroni corrections revealed a significantly higher mean in 10-length condition than in Distracter-matched condition (mean difference = .052, $p = .005$), and Target-matched condition (mean difference = .083, $p < .001$).

This indicates that the superior performance of 10-length condition against conditions made up of more closely separated pairs is not attributable to the individual positions of its distractor

(distant) or target (recent) items, as each of these were matched in one of the comparison conditions (Distractor-matched and Target-matched). This demonstrates items that are more separated are easier to be remembered. This is in line with the findings from previous JOR studies, such as Fozard (1970) and Toggia and Kimble (1976), using the interleaved paradigm, and Tzeng and Cotton (1980) using a study-test paradigm, and moreover provides the controls that establish that this effect is above and beyond the fact that wider pairs tend to contain items from closer to test and positioned nearer to item terminals.

Presence of terminal items. The data within test conditions two and three were then backsorted into three bins of fifteen scores, containing scores from pairs that included an item within the first five positions, last five positions, or neither respectively. This yielded proportional accuracy scores on Start pair judgments (summary of scores on pairs from 1–6 to 5–10, repeated across three trials), End pair judgments (summary of scores on pairs from 11–16 to 15–20, repeated across three trials) and Middle pair judgments (summary of scores on pairs from 6–11 to 10–15, repeated across six trials and then divided by two). The means (and S.D.s) for these accuracy scores were Start pairs .858(.132), End pairs .796(.153) and Middle pairs .818(.112).

An ANOVA was computed for these three conditions and indicated a main effect for position: $F(2,106) = 4.873$, $p = .009$. Pairwise comparisons employing Bonferroni corrections revealed that this was due to significantly better performance in early pair judgments than middle pair (mean difference = .020, $p = .044$) and late pair (mean difference = .031, $p = .022$).

This indicates that presence of items from first five positions in trial pairs produced better performance compared to more centrally located pairs. Items within the last five positions did not have a significant effect compared to middle pair. Proximity to start benefits accuracy of judgment whilst proximity to the end does not for closely separated items.

Terminal item position by separation interaction. To investigate the relative effect of terminal item positions, and also to see whether there is an interaction with item separation, the data from the 10-separation condition was split to produce accuracy scores derived from early items and accuracy scores derived from late items for each participant. This produced four groups, an early position/short separation group composed of pairs 1–6...5–10, an early position/long separation group composed of pairs 1–11...6–16, a late position/short separation group composed of pairs 11–

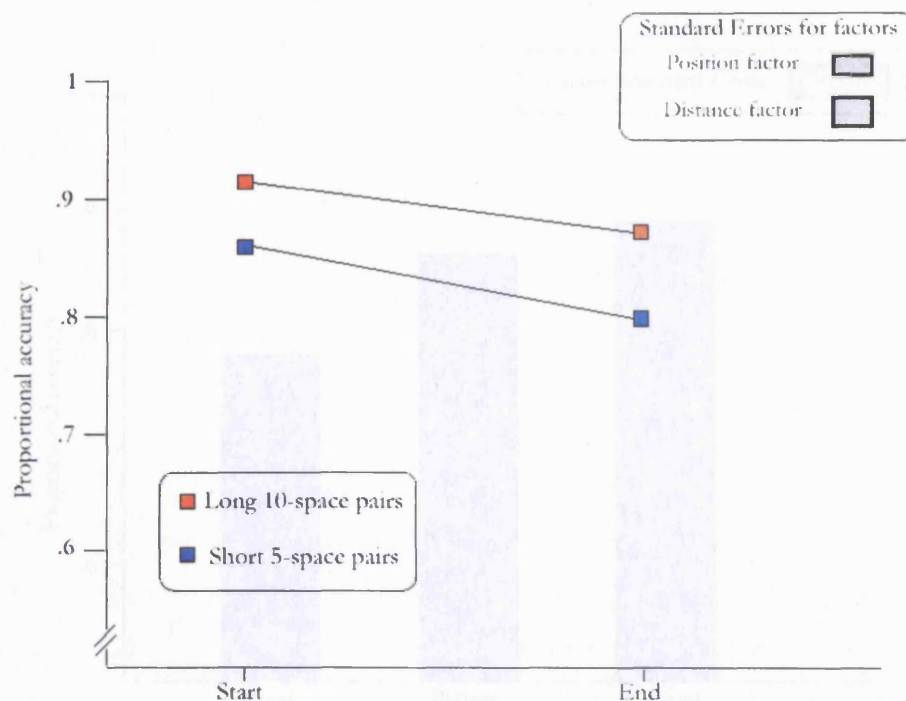


Fig. 2.4: Interaction between position of terminal item and pair spacing.

16...16-20, and a late position/long separation group composed of pairs 6-16...10-20; their mean accuracy scores are shown in Figure 2.4.

To test for differences and additionally to consider the effects of presentation speed, a 2X2X2 (position by separation by presentation speed) ANOVA was conducted. This revealed reliable main effects for position: $F(1,52) = 18.864$, $p < .001$ and distance: $F(1,52) = 15.106$, $p < .001$. No interaction between these two variables was revealed. This further attests to the way in which pair separation has an effect separate to the contributions given by its component items, and suggests that the two effects may reflect different mechanisms.

Presentation Rate. The fall in accuracy when presentation of items was reduced from five seconds to 2.5 seconds per item was merely from .85 to .84. There was no main effect of this difference and no interactions were found between presentation rate and item position or inter-item distance. Simple manipulations of presentation rate of a study list appears to have no effect upon accuracy of ordering items from that list. This result is consistent with positional and contextual models but jibes less well with theories that presuppose that time is a critical currency in order judgments.

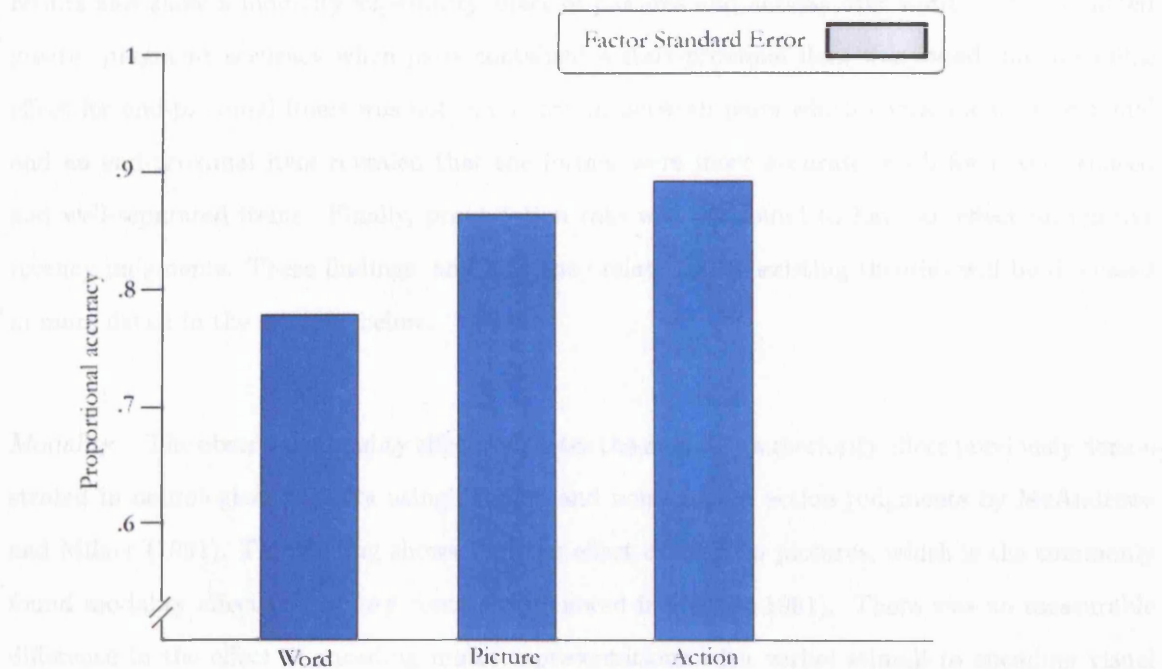


Fig. 2.5: Performance across items for each modality.

Modality. The pattern displayed by the data is shown in Figure 2.5; performance was best in the action condition, scoring .893(.1047), intermediate in the picture condition scoring .865(.093) and worst in the word condition, scoring .780(.026). A separate ANOVA for modality revealed a reliable main effect of modality: $F(2,52) = 18.414$, $p < .001$. Pairwise comparisons employing Bonferroni corrections revealed a reliable difference between pictures and words (.085 mean difference, $p < .001$), and actions and words (.120 mean difference, $p < .001$) but no reliable difference between pictures and actions (.035 mean difference, $p = .133$). This demonstrates a memory modality effect in order judgments.

Item pair accuracy. The data was summed across participants to provide accuracy scores on each trial pair; this is shown ranked from worst to best performance in Appendix A. This was not formally analysed, but examination of scores bears out the positional findings described above; namely that performance was best for early items and well spaced pairs.

Discussion

This experiment looked at the effects of a number of different variables on recency judgments. These findings show that distance between items in a trial pair has an effect in the predicted

direction, such that judgments are more accurate when made between more spaced-out items. The results also show a modality superiority effect of pictures and actions over words. The predicted greater judgment accuracy when pairs contained a start-proximal item was found, but a similar effect for end-proximal items was not. Comparison between pairs which contain a start-proximal and an end-proximal item revealed that the former were more accurate, both for closely-spaced and well-separated items. Finally, presentation rate was not found to have an effect on relative recency judgments. These findings, and how they relate to the existing theories will be discussed in more detail in the sections below.

Modality. The observed modality effect replicates the modality superiority effect previously demonstrated in neurological patients using enacted and non-enacted action judgments by McAndrews and Milner (1991). This finding shows that the effect extends to pictures, which is the commonly found modality effect in memory research (reviewed in Paivio, 1991). There was no measurable difference in the effect of encoding motor representations with verbal stimuli to encoding visual stimuli with accessible verbal labels. These superiority effects have been suggested to be due to dual coding which produces multiple representations which aid in making memory judgments about the original event (Paivio, Rogers, & Smythe, 1968). The results obtained here can be seen to support this, insofar as information coded as more than a purely verbal input produced facilitated judgment, regardless of the exact input they were given. The results were not consistent with an account in which the advantage enjoyed by enacted items is due to privileged access to order information.

As this applies to temporal memory and recency judgments, it suggests that encoding more information about an item makes it easier to discriminate temporally. This does not fit neatly with chronometer accounts, as this dictates that temporal judgments are not done on the basis of actual item information but on an associated temporally dependent code which is produced fairly automatically by an internal chronometry system (see Naveh-Benjamin 1990 for a discussion of the supposed automaticity of temporal encoding). This seems to suggest the information participants are using relates to item information or non-specialised contextual information of a similar kind to those made in other judgments of sources of memories. Johnson, Hashtroudi, and Lindsay emphasise how such successful source monitoring relies on differences of characteristics within the memory, with an emphasis on “fully contextualising information at acquisition” (Johnson et al., 1993, pg 5). This may be disrupted by a high load at encoding, and result in items that may be encoded but poorly embedded with contextual details about other items. It also demonstrates

that the primacy effect and absence of recency effect generalises to two types of visual stimuli and additionally stimuli that are enacted.

Temporal separation of items. The rate of item presentation within study lists was varied across groups, and participant performance was shown to be unaffected. Chronometer accounts of temporal memory suggest that items are encoded into memory along with temporal codes taken from the operation of internal time-keeping devices, and that these codes are, according to the ratio rule, best discriminated when there is a high ratio between the time elapsed since encountering each item (G. D. A. Brown & Chater, 2001). This fairly simple manipulation is not an ideal test of this, as lengthening presentation rate does not have a focused effect on such ratios, as both items are pushed away from the present. These ratios would not however be unchanged, and the shift would be most marked for end items: for example the time elapsed at test from item 20 is the same under both rate conditions (as no items follow it, the slower presentation rate has no effect) whilst the item it is paired with is more temporally distant by either ten (for item 16) or 22.5 (for item 11) additional seconds, inflating the ratio between the two. The lack of any evidence of differential performance at longer presentation rate, such as better performance on End items, gives us no evidence in support of these accounts.

Pair separation. Performance in the 10-separation condition was found to be significantly greater than that in either of the comparison conditions (Distractor-matched and Target-matched). The common distinction between 10-Separation and the comparison conditions was the item separation of each trial pair, with 10-Separation composed of targets positioned ten places ahead of distractors, and the comparisons containing targets positioned five places ahead of distractors. As inter-item separation partially determines position of pair items, a single condition was not free to vary with the 10-separation condition. If separation is varied then item position cannot be held constant. However, the greater performance of 10-separation condition against the distractor-matched condition reveals an effect of separation that cannot be attributable to distractor (early) item position. Similarly the greater performance of 10-separation condition against the target-matched condition reveals an effect of separation that cannot be attributable to target (late) item position. This suggests a real effect of separation that is not attributable to the effect of items within a single position, but rather the distance between positions, or at least interaction between positions (which cannot be obviously untangled — in any case the two are clearly conceptually close).

This finding accords with the predictions of compound chaining models of Elman (1990), as well as those of positional models such as the Start-End Model (Henson, 1998b). It is inconsistent with simple chaining models (e.g. Wickelgren, 1965), and not adequately explained by the order-code theory (Tzeng & Cotton, 1980) of long-term temporal memory. The former supposes that pairwise associations between adjacent items produce information about their order, so as a consequence intervening items should make the task more difficult. The latter argues that displaced rehearsals lead to associations being made between items that code their ordinal relationship. It is difficult to see why this should occur more for further-spaced items, and their attempt to accommodate it — suggesting that widely spaced items result in more intervening items that could potentially both cue the distractor and be cued by the target, acting as a kind of study-phase retrieval middleman — smacks of special pleading, especially as it requires that greater-separated items are distinguished by a multi-step process, which should make it more prone to error. This results consequently offers a more stringent replication of the result found in earlier studies (Fozard, 1970; Tzeng & Cotton, 1980; Toglia & Kimble, 1976; Yntema & Trask, 1963) of an effect of greater separation upon the accuracy of temporal judgments in the JOR paradigm.

Item proximity to a terminus. The effect of greater judgment accuracy in pairs containing start-proximal items can be seen as an example of the primacy effect, documented both in recall accuracy (Murdock, 1962), and previous temporal memory research, including work made upon relative recency in pairs (Tzeng et al., 1979). The lack of a corresponding recency effect is inconsistent with that found in earlier studies that used serial recall (Hintzman & Block, 1971; Toglia & Kimble, 1976). One possibility is that recency may be only limited to the very terminal items, in this experiment perhaps the 19th and 20th items from the list. Examination of the overall accuracy of judgments on pairs given in Appendix A does not bear this suggestion out: when judgments involve the 19th and 20th positions, and are not facilitated by a great separation between items, they fall into the lower half of the accuracy table; this can be compared with their start-list equivalents, which make up the first four positions irrespective of whether the other item was closely or distantly separated. This divergence between findings from serial position and recency judgments has important implications; it suggests that those aspects of memory that enhance performance on lists of recall may have little or no role to play in judgments of recency made on those same items.

Terminal item position by separation interaction. The above finding shows that for 5-length trial pairs, Start items are of more benefit to judgments than middle and end-proximate items. This is also the case for 10-length trial pairs, and the two effects of separation and Start/End proximity showed no interaction. It is reasonable to suggest from this that the benefits of judging start items and well-separated pairs are largely independent and additive. Thus several cognitive processes are likely to contribute to JORs under these conditions.

The relative ease of making temporal judgments on items that are well separated have been described above; it supports compound chaining and positional models over simple chaining and order-code theory as accounts of long-term recency judgment-making. Higher accuracy for start over end items regardless of distance is a more surprising finding. Whilst this does not pose a problem for position models (Conrad, 1965; Lee & Estes, 1977) that do not implicate the end of lists in positional codes, it is inconsistent with the SEM (Henson, 1998b). This model posits that items are coded relative to the start and end of a list and predicts both primacy and recency effects (indeed, it was constructed precisely to account for these effects). As such this finding does not offer support for the same processes operating at longer time intervals; however it is not incompatible with a more general positional account. Henson has cautioned that to be able to reliably order items via end-coding the degree of expectancy of the end must be sufficiently high and accurate; these criteria may not be met in longer-term paradigms such as the one employed. This finding may be compatible with reconstructive models where the start of the list provides a salient point against which nearby items may be coded.

The models of chronological organisation suggested by G. D. A. Brown and his colleagues (OSCAR, G. D. A. Brown et al., 2000; SIMPLE, described in G. D. A. Brown & Chater, 2001) seem less able to accommodate this finding. Although based on data from short-term paradigms, they claim that the temporal discriminability upon which temporal organisation is achieved is time-invariant. The OSCAR model assumes the involvement of a series of oscillators working at different timescales and its exact implementation is complex; its successor SIMPLE has not been formally articulated in the literature. What is clear is that these models are underpinned by “the idea that the retrievability of items from memory will have ratio-like qualities - that is, the relative discriminability (and hence retrievability) of two items will depend on the ratio of their temporal distances.” (G. D. A. Brown & Chater, 2001, p96). One outcome of this ratio rule is that a pair of items that were presented recently will be better discriminated than an equivalently spaced pair of items presented remotely. This rule can in fact be formalised:

$$\text{temporalratio} = \frac{r(i - s^d) + p + t(j - 1)}{r(i - s^r) + p + t(j - 1)} \quad (2.1)$$

i = number of items in study list, s^d = study position of distractor, s^r = study position of recent (target) item, j = test position of JOR, p = period between study phase and test phase, r = rate of study list, t = test rate.

Using this equation, one can derive the temporal discriminability of two items seen in a list, if information about their relative position to one another and absolute location relative to the time of test is available. The equation can be modified to allow the calculation of the average value for a specific JOR pair across a number of test positions:

$$\text{temporalratio} = \frac{r(20 - s^d) + p + t(\frac{\sum_{j=1}^{n-1}}{n})}{r(20 - s^r) + p + t(\frac{\sum_{j=1}^{n-1}}{n})} \quad (2.2)$$

where n is the number of test positions — ten in the present case. I have chosen to assume a number of values in order to assess predicted performance under conditions similar to those in Experiment 1. Specifically I assume a fixed value of 4 seconds for t , the rate at which test trials are presented, and a value of 4 seconds for p , the transition lag between the end of study list and beginning of test list. r can be fixed at 3.5 (comparable to the 2.5 second presentation of items plus 1 second inter-item interval employed in Experiment 1). Use of these values together with Equation 2.2 yields the pattern of predicted performance shown in Figure 2.6 for JOR pairs separated by 5 positions. It should be noted that the pattern depicted in the figure cannot be mapped neatly onto actual data, for whereas JOR proportional accuracy has an upper limit of 1.0 no such limit can be placed on the temporal ratio, which can be indefinitely extended by pushing back the position of the distractor, or bringing target and test time ever closer. Nevertheless, it can provide us with directional information about what effects temporal ratios ought to have on JOR data if they are a factor in distinguishing items in time.

As can be seen there is a graded recency trend where items nearer the end of the list outperform their more remote counterparts. It is clearly not the case that the present data follows this trend, as the most recent items do not outperform the intermediate items, with the early items showing most advantage. This is suggestive that the reconstruction of order of items from a list or minutes duration is not achieved using temporal discrimination, hence this is not a time-invariant strategy.

The current paradigm does not allow us to pose a strong argument against this view of temporal memory, as the use of the above formula requires certain values which this experiment does not yield

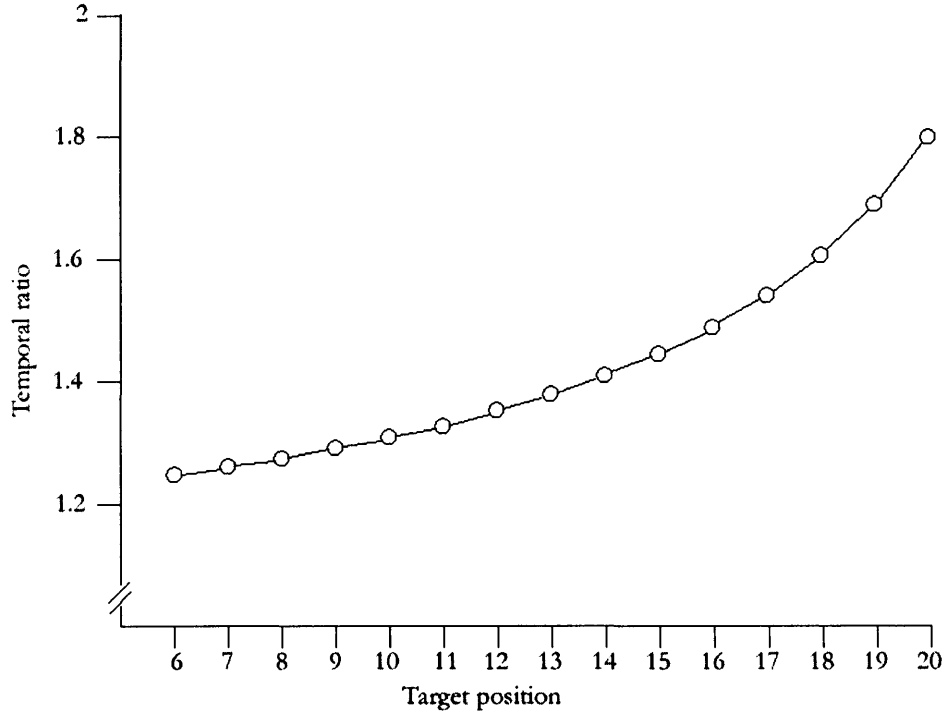


Fig. 2.6: Derived temporal ratios for JOR targets under ideal paradigm conditions.

with any certainty. As this experiment was unspeeded, it is possible that some participants lingered on the screen in between study and test, creating a high value of p , or spent the occasional long gaps in between judgments to ponder their response, inflating t ; both outcomes serve to increase the values of both numerator and denominator, with the net effect of lessening the contribution to the equation of the other aspects, s^d and s^r , that shape the size of the ratio. Data from pilots suggests that responses tend to be fairly fast, generally within 1–3 seconds, but because this has not been explicitly controlled my comparison between idealised performance and the data is difficult to make.

In employing Equation 2.2, Figure 2.6 also assumes that each judgment occurred equally across each test position (and each value of t). This aspect of the task was left to chance rather than systematic randomisation; although the large sample and number of blocks makes a gross imbalance unlikely, this assumption is unproved. Whether or not these assumptions are sound is irrelevant to evaluation of the SEM, as the issues explore here concern list position rather than time elapsed from presentation to test. However, to corroborate the mismatch between the findings of experiment one and the G. D. A. Brown position requires altering the experiment to control against participant-induced fluctuations in timing. This manipulation is the main motivation for Experiment 2.

Experiment 2: Controlling For Temporal Variables

Experiment 2 aims to replicate the basic findings of Experiment 1 using a paradigm that would allow a direct comparison with the predictions derived from a temporal ratio view of temporal memory, as presented in Figure 2.6. The temporal discrimination hypotheses instantiated in models of G. D. A. Brown and colleagues, as formalised in equation 1, lead to the prediction of a temporal gradient showing better performance with more recent items. For this pattern to hold certain conditions must be met that involve the rate of presentation of study items, test pairs, and the interval which separates them. Experiment 1 determined the first of these factors, but left the others indeterminate. Here I rectify this via three modifications, aimed at controlling the variables described in equation 1.

These modifications are automatic trial transition, factorial counterbalancing, and automatic test-phase transition.

- Modification one involves test trial transition, in order to control for variable t . Rather than allowing each trial to be of indeterminate length, allowing participants as much time as they wish to make decisions, the program determines trial transition, with onset from one to the next occurring automatically. This allows us to combat the possibility that participants may be pausing mid-test or spending an unusually long time on every item, spinning out the distance from presentation for later items and with the effect of reducing the posited advantage for recent items.
- Modification two involves varying the test position of JOR pairs factorially, such that each test pair is presented once and only once in each of the test trial positions. Each test phase is composed of ten trials, and this design, along with that described above, ensures every JOR pair is presented at the same fixed intervals from the end of the study phase, with no pair presented further from the study phase than any other. This allows us to derive a mean t from each of its values at every test position.
- Modification three involves the test phase commencement, in order to control for variable p . The progression from study to test phases was automated, such that following the end of the study list, a short warning is presented before an automatic onset of the first test trial. Similar to modification one, this combats the possibility that participants are pausing after viewing the study list, which would have a disproportionate impact on the discriminability of recent items.

Modification one augments the design in a further way. It allows the testing of a novel prediction based on temporal discriminability. The prediction is that items presented late in the study list will benefit greatly from being presented near the beginning of the test phase, whereas items from the beginning of the study list will see no real effect. This is due to the disproportionate impact delay has on large ratios (involving recently experienced items) as opposed to small ratios: the rate of reduction of the temporal discrimination of the first and last pairs as they are tested increasingly later.

It should be noted that whilst this is intended to address the hypotheses of (G. D. A. Brown, 1997) and other proponents of temporal discrimination, it is not intended to test the computational models themselves; rather, it is directly testing the principle that underpins it of the proportional temporal distance of items resulting in their temporal distinctiveness. Under this perspective Target 20 should see a far greater change in performance as test position is increasingly delayed than seen for Target 6, if temporal discrimination is a useful information source for making these judgments.

Because of the nature of temporal ratios, this offers us a far more convincing test of the principles underlying this chronometric memory position. The temporal ratios described in Figure 2.6 are across all trial positions, and this averaging means that even the most favoured target (20) is not more than 1.5 times more discriminable than the least favoured (6). As can be seen in Figure 2.7, the model predicts that when target 20 is presented in the first trial position, its temporal discriminability is over three and a half times better than if it were presented in the last trial position, and four times greater than that of target 6 across any of the test positions. This is effectively employing a single probe of order memory (see e.g., Avons, Ward, & Melling, 2004). Interest in order memory at longer durations than those employed in the short-term memory literature means the employment of single probes of order memory is untenable, requiring as it does many study phases (e.g., in the study of Avons et al. (2004), the use of ninety phases per experiment, a tenfold increase on the quantity within Experiment 1). Consequently this comparison must be a supplement to the established procedure of comparing Start and End items across positions.

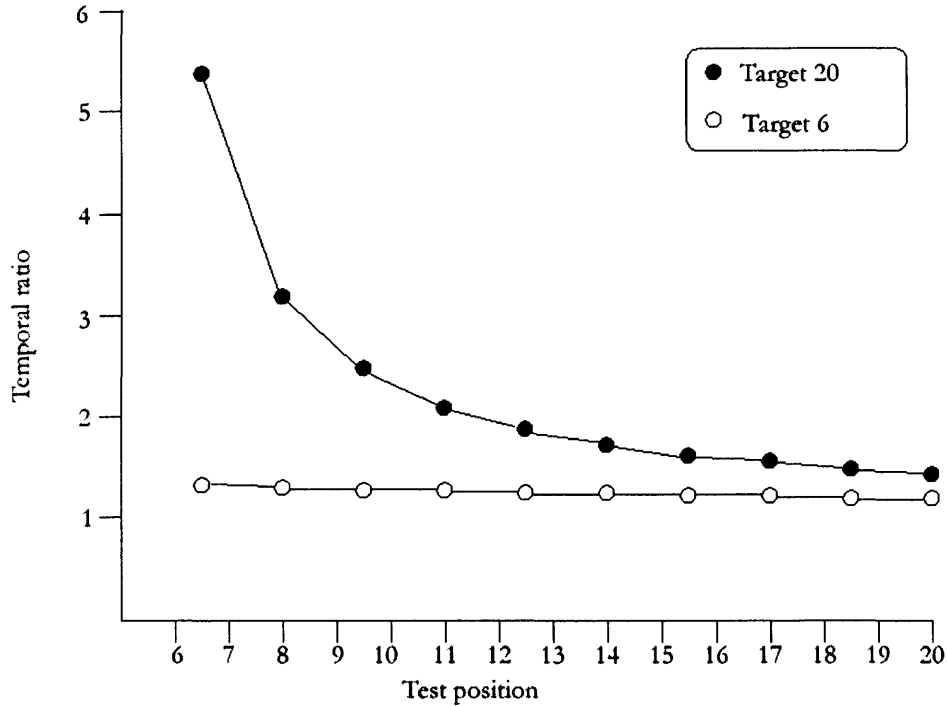


Fig. 2.7: Temporal ratios for JOR pairs 6 and 20 across each test position.

Method

Materials and Participants.

This experiment was run as an executable program written on Visual Basic, similar to previous experiments. All study lists are composed of words from the MRC psycholinguistic database. All words used were concrete nouns, matched for familiarity, concreteness and imagability, as dictated by Paivio norms (Paivio, Yuille, & Madigan, 1968).

Seventy participants took part in this experiment (50f, 20m, 15–58 years, M 23.7). Participants were chosen opportunistically from the Psychology department. All participants had English as a first language and normal or corrected to normal vision.

Design.

The study followed a repeated measures design, with two independent variables: the order of the test pair presentation (ten levels, across lists) and the original study list positions of the test pairs

(either containing a start or end item — across lists). The study phase is essentially identical to that in Experiment 1, except that only words were used as stimuli. Dispensing with the three conditions used previously this experiment streamlines the test conditions to focus on these pairs of interest: five pairs that contain start items, and five that contain end items. It also dispensed with the unwelcome need to re-present items twice in a test phase (e.g. 6–11 and 11–16), which was a requirement only for matching between different pair separations. Consequently each test phase is composed of the pairings 1–6, 2–7, 3–8, 4–9, 5–10 — start pairs — together with 11–15, 12–16, 13–17, 14–18, 15–19, 16–20 — end pairs. For convenience pairs will be referred to by their target item, the most recent one, as this now determines all the necessary information about the pair; hence Target 20 denotes performance on JOR pair 16–20. The order that the test pairs are presented is systematically varied, such that a given pair (e.g. Target 6) is presented first in one test phase, second in another and so on such that it is presented in each of the ten test positions, across ten different test phases. The exact allocation was pseudo-randomised to avoid pairs of items that were adjacent at study being presented consecutively at test, producing 10 complementary pair order sets. For example, one pair order set (Set 1) is composed as follows: targets 20, 19, 18, 9, 16, 7, 8, 6, 10, 17; target 20 appears at positions 2 to 10 in the remaining pair order sets, and 19 in position 1 and positions 3 to 10, with the other sets not resembling set 1 but being non-random only by virtue of the fact that no target reappears at the same position twice. Participant k underwent test phases beginning with pair order set k , followed by $k+1 \dots k+9/k-1$ — cycling around to lower ranked pair order sets as appropriate. These pair order sets are presented in full in Appendix B.

Procedure.

The general procedure is similar to Experiment 1. In this case, participants are presented with the requirements of the task before the study, and made familiar with the method of responding. They are also warned about the automaticity of several stages, and that JORs must be made within a limited period of time, guessing if absolutely necessary. They are then presented with ten study lists, each followed by test phases as before. Each study phase is followed by an instruction screen which is presented for four seconds, after which the test phase begins. Each test pair is presented for four seconds, during which the participant must make a judgment via keyboard presses. If no judgment is made by the beginning of the fourth second, a warning signal urges the participant to immediately make their choice. Following this the next test pair is presented. As before all information is stored into a text file. After the test phase, participants are presented with another instruction screen, and must make a keypress to proceed to the next study list.

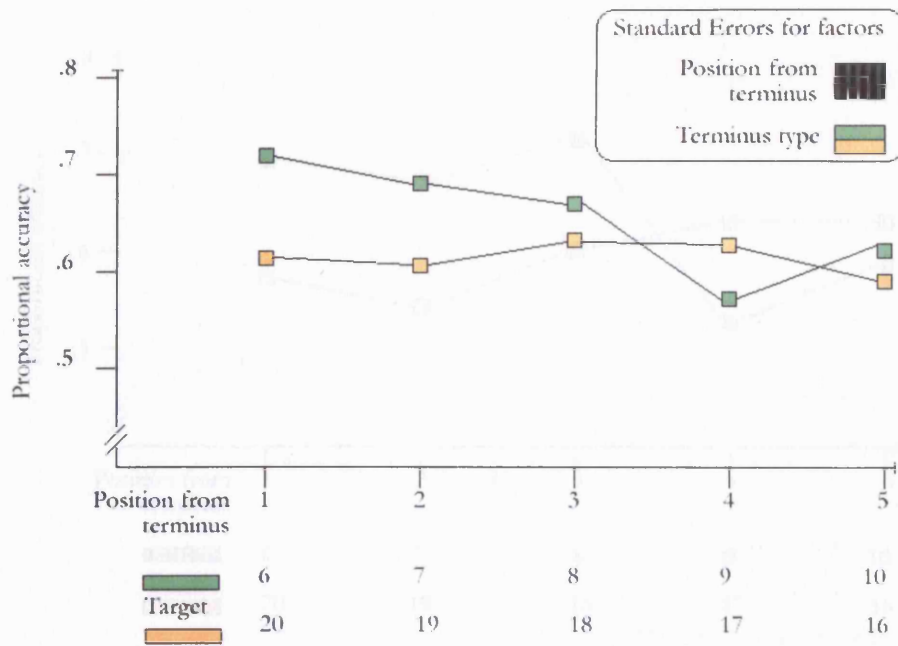


Fig. 2.8: JOR Accuracy for Start and End pairs displayed as a function of the proximity of the pair item nearest a list terminus to that terminus.

Results

As in Experiment 1, of critical interest is whether pairs containing items from the end portion of the list will outperform those containing items from the beginning. The ten data points in every test phase was split into two bins, one for Start Pairs (defined as those containing targets 6 to 10) and one for End Pairs (with targets 15 to 20). Judgments on Start items, at .66 (.141) accuracy, outperformed those for End items, at .61 (.124) accuracy. It should be noted that these scores are lower than those found in Experiment 1. This difference between Start and End Pairs was revealed to be significant, $t(69) = 2.938$, $p = .004$. Performance for each JOR pair is presented in Figure 2.8, wherein Start and End items are presented as separate lines, beginning with the items that would most benefit from primacy and recency effects respectively. As can be seen, a clear curve exists for Start items with items one to three from list onset showing particularly notably better performance. With end items, no suggestion of a recency effect exists.

Also of interest in this experiment is the way in which JOR type interacts with test position. It should be emphasised that looking at these cases depends on sums of individual binary scores — for every participant, whether they correctly judged the order of that pair the single occasion they were presented with it at that test position.

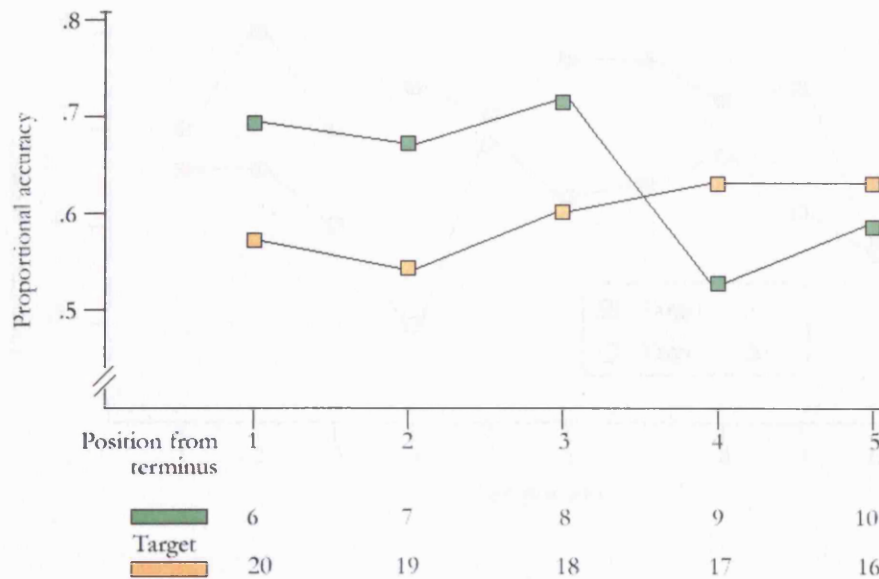


Fig. 2.9: JOR Accuracy for Start and End pairs as a function of pair proximity to list terminus when JOR is presented at Test position 1. Note that standard error bars are not given for this figure as the data is binary (each participant either makes a correct JOR for that target or an incorrect one).

The ratio rule predicts that items tested immediately after study should show a strong recency effect. Figure 2.9 demonstrates such a single probe situation, by showing performance for each JOR at test position 1. As can be seen, performance is markedly better for the first three JOR pairs. A chi-square on all items reveals that scores are distributed non-randomly, $\chi^2(9)=21.464$, $p<.025$; when targets 6, 7, and 8 are removed from the analysis the analysis shows no difference between scores, $\chi^2(5)=2.637$, $p=.75$. This simulation of single-probe recognition thus reveals no superiority for End items.

Another approach is to compare the way in which performance changes over test positions for different test pairs. Figure 2.7 displays hypothetical performance for targets 6 and 20 as the presentation of test trial is increasingly delayed by interposition of other test trials. The curves shown are based upon the ratio rule and the timings involved in this experiment. As can be seen, the rule would predict performance for target 20 to rapidly fall off over the first two positions, and then more shallowly decrease. Target 6 displays a flat curve. Figure 2.10 presents actual data from this experiment for these two targets. It can be observed that no greater trend can be observed for one than the other.

Aside from the special case of the last studied item, the overall relationship of JOR accuracy

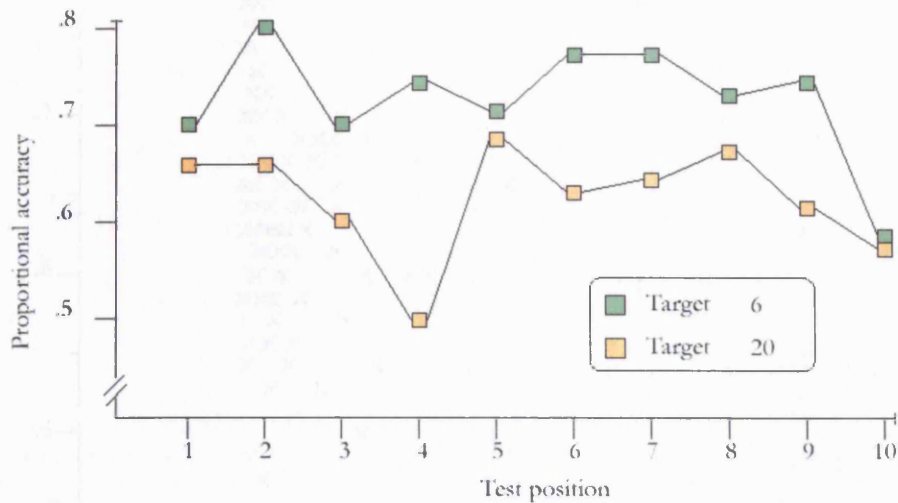


Fig. 2.10: JOR Accuracy for Targets 6 and 20 as a function of test position.

and temporal discrimination value for each judgment can be assessed, in order to see whether there is a tendency for pairs with a greater temporal discriminability to lead to more accurate JORs. Figure 2.11 shows a scatterplot in which every point is one of the hundred possible Test position (1–10) by Target (1–6; 16–20) combinations. The x axis depicts the temporal discrimination value for that item based upon Equation 2.1, whereas the y axis depicts accuracy across participants for that item. Most scores are toward the left of the plot, as ratios tend toward 1. A correlation reveals a negative but non-significant relationship between the variables, $-.139$, $p = .168$.

Discussion

This experiment replicates the finding from Experiment 1 that Start items are more easily temporally distinguished than End items in the Study-List JOR paradigm. This holds under a set of control manipulations that ensure that the task proceeds within a regular timetable that allows some assessment of the predictions derived from the ratio rule driving temporal discrimination accounts of order memory. It further shows that contrary to temporal discrimination theories, pairs including the most recent study item do not show superior performance when tested first, nor is that pair's pattern of performance across test position distinct from that of other pairs. Over all judgment pairs at every test position, there was no correlation between JOR accuracy and the temporal discrimination value derived from Equation 2.1.

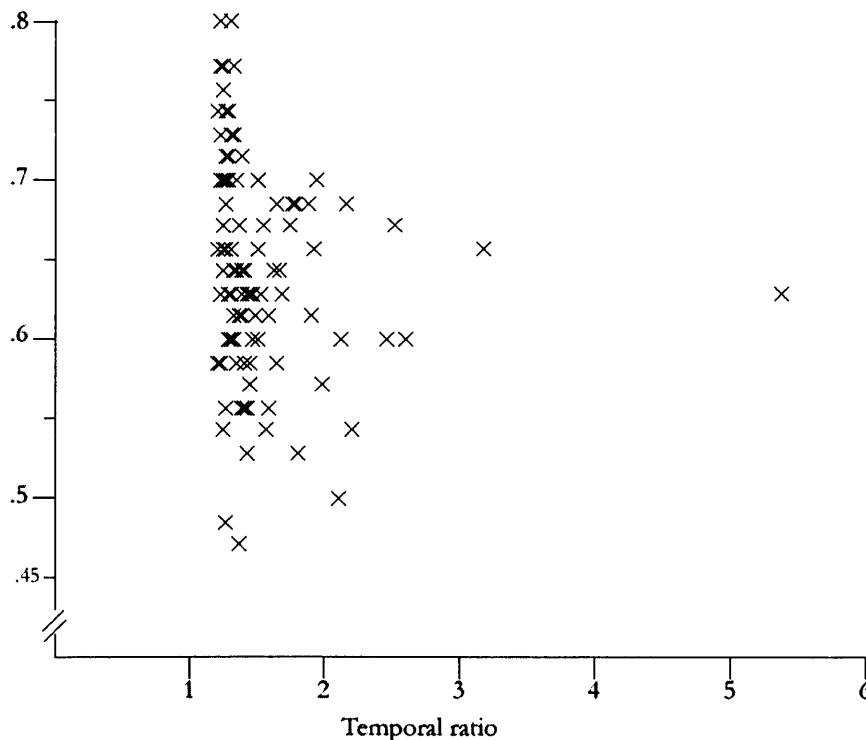


Fig. 2.11: Overall accuracy plotted against temporal ratio for each JOR target at every test position.

Many investigations put a premium on the immediate testing of recency items, such that they are “truly” recent, and to do so employ single probe recognition or interleave study and test trials. These predictions do not require such designs, as the ratio rule derives superior scores for recent pairs even when averaging across test positions. Recent pairs possess greater discriminability, and if this value is useful in making order judgments, performance should be accordingly better. That this is not the case presents problems for theories that suppose that some instantiation of a ratio rule produces temporal information that is useful in making order judgments.

Although as I suggest above “true” recency is not necessary to assess the predictions derived by the ratio rule, it is the case that this rule predicts largest values (and correspondingly highest performance) for those final study items when they are tested first. The use of the trial order counterbalancing yields a design which provides an effective single probe comparison allowing comparison of performance at the first test position for each trial pair. In this case performance is markedly better for judgments involving the first three items, and shows some non-significant recovery for performance involving the last three. This is not what the temporal discriminability hypotheses, based upon the ratio rule, would predict: performance should show graded recency, with best performance for the last items to be seen.

Moreover, for a given JOR pair it is possible to compare performance at every test position. As the ratio rule predicts superior performance for recency items when tested first, but rapidly less so thereafter, it should lead to a steep curve for a pair such as Target 20. Intermediate and early items would by comparison show shallow curves. The data does not bear these predictions out. This lack of sensitivity to test position suggests that Target 20 is not being assessed using temporal discrimination information of this kind, even though this is the case that would benefit most from doing so. Moreover, temporal discrimination and accuracy show no relationship with one another across the JOR pairs and test positions, which suggests that the limited case of Target 20 is indicative of the paradigm as a whole.

It should be noted that the performance seen in Experiment 2 is substantially lower than that in Experiment 1, an outcome not readily predicted from any of the theories discussed above. One possibility is that participants actually prefer to perform the experiment at a greater rate than that enforced, by rapidly clicking through the screen separating study and test, and making each judgment on the heels of the last. In this case the manipulations that were employed to give a fairer assessment of recency under the temporal ratio hypothesis would have done the reverse. Under that hypothesis enforcing the experimental rate would harm End items and have little or no effect on Start items. This is not the pattern presented by the data, with judgments on both types of items suffering. This is also not in line with the report-backs that participants give, nor the typical reaction time of responses to items (note also that participants are not prevented from reacting immediately to JOR pairs, which might be expected to interfere with the strategies used in the previous experiment; rather, the onset of the next pair is enforced). Rather, participants reported that the rapid onset from study to test and the limited time window for response was pressured and forced responses from them. The poorer performance may instead be indicative of a preference to employ reconstructive strategies when items do not impress their position immediately by dint of a simple association.

In summary, this Experiment presents evidence that temporal discrimination values for pairs of items do not reflect accuracy of JORs made upon them, neither in the general case (correlation across all points) nor for the strongest candidate of the latest (recency) pair, for which accuracy does not show a relationship with test position, nor does it outperform other pairs when presented first. Instead, items from the start of the list lead to more accurate JORs. This suggests that the temporal discrimination ratios yielded by the ratio rule are not noticeably contributing to decisions regarding the positions of items in a LTM recency task.

Experiment 3 — The Role Of Expectation

Experiment 2 addressed aspects of the temporal discrimination models (and the predictions they derive) that Experiment 1 could not fully resolve. This experiment serves a similar purpose for the Start End model (Henson, 1998b), which I have suggested is not supported by the findings of Experiment 1, particularly the Primacy effect in the absence of a Recency effect. This result was to some extent anticipated by Henson, who addresses the problem of the action of the end marker thus:

One question concerns how the influence of the end marker can extend backwards in time in the coding of temporal order. It was originally proposed that the strength of the end marker might correspond to the degree of expectation for the end of a sequence....the predictability of the end of a sequence is at least one experimental manipulation that is likely to affect the behaviour of SEM's end marker (Henson, 1998b, pp121–122).

For Henson, working with short-term memory paradigms, expectancy is achieved if lists are of a determinate length. At the current time-scale, however, fixed length is insufficient to achieve this, unless participants are explicitly counting down through the list, a strategy which was not reported. The onset of list end is indeterminate, and can be at best estimated. Tzeng et al. (1979) raise this as a possible impediment to coding positional information at longer time-scales. As such, the choice of task may act to render useless the end marker, through making it impossible to anticipate.

Although it is the case that some mechanisms appear to exist that allow sudden events to alter representations of previously occurring events — the “temporal paradox” of conditioning (Doty, 1979) where the conditioned stimulus is altered by the subsequent unconditioned stimulus — this appears to be a narrow case requiring repetitive schedules and a limited timescale. As such, should end-coding be a viable strategy or mechanism for participants at the present timescale, it does appear critical that reasonably accurate expectancy is available for participants studying lists to allow them to subsequently make accurate temporal judgments. Under this hypothesis, an experimental manipulation to restore “expectation for the end of a sequence” should provide selective benefit for End items by increasing its strength. In this experiment, such a manipulation is achieved by the use of a visual marker providing a guide to how far the list has progressed, and how near it is to its end. Rather than using a discrete marker such as a ticking clock face, numerical

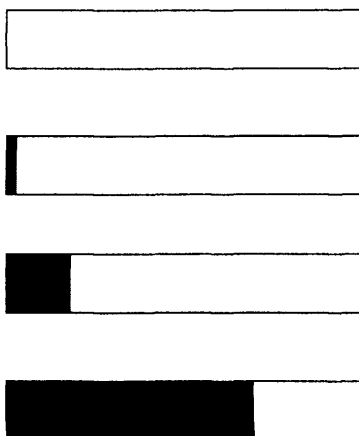


Fig. 2.12: Filling bar graphic employed in Experiment 3. Displays components 1,2,7 and 27.

countdown or other cue which could be directly associated with items and allow another route to solving order judgments, the experiment employs a relatively continuous filling bar similar to that presented in a web browser when loading pages. Using this participants cannot find themselves lost in the sequence of presented items and will always be aware of when they are in the last leg of the study list, allowing them to encode items against end markers if this is within their ability to do so. Based on Henson's suggestion, I predict that when a filling bar is presented End items will enjoy a boost in performance relative to a control condition.

Method

Materials and Participants

, Thirty-six participants (19m 17f, 18– 54 years, M 21.65) were recruited opportunistically from UCL campus. All participants had English as a first language. The program used was an adaptation of that used in Experiment 1, amended for the change in number of blocks and type of stimuli, and the addition of an additional graphical feature (a filling bar). The filling bar was placed in a position on screen below and somewhat to the right of the area within which the study items were presented. Its dimensions were 2175x375 twips, a computer screen measurement; as one twip is 1/1440th of an inch, this is approximately 1.5 inches long and .26 inches in height. This dynamic bar was effectively a set of forty images presented sequentially in overlay, the first an entirely white rectangle and the fortieth an entirely black one, with intermediates filling in with black from left

to right in a regular fashion. Examples can be seen in Figure 2.12 . This experiment was carried out earlier than Experiments 2 and consequently does not share the design components of factorial counterbalancing, automatic test-phase transition or automatic trial transition; on these matters they are identical to Experiment 1. The composition of test pairs is however similar to that used in Experiments 2.

Design

This experiment employed a 2X2 within-subjects design, where one factor (presence of filling bar) varied across blocks and the other (original study position of test items) varied within each block. The task was composed of 4 blocks. The study items were drawn without replacement from a pool of words from the MRC psycholinguistic database. All words used were concrete nouns, matched for familiarity, concreteness and imaginability, as dictated by Paivio norms (Paivio, Yuille, & Madigan, 1968). Half of the study blocks involved the presentation of a filling bar below the stimuli. Half the participants received the filling bar on Blocks 1 and 3, the other half on Blocks 2 and 4. The test phase, similar to Experiment 2, was composed of ten trials presenting pairs of 5 separation, five involving Start pairs (targets 6–10) and five involving End pairs (targets 16–20).

Procedure

The procedure is very similar to the previous experiments. Participants were informed they would be presented with a series of lists of verbal stimuli, and after each list would be tested for order memory. They were informed that on two of the four lists they would be aided by a “filling bar” to help them monitor their progress through that list. On such experimental blocks, a series of pictures were presented sequentially in the bottom right of the screen such as to create a fairly continuous animation of a white bar filling up black from left to right. Transition between images occurred with the onset of each item, and precisely between each onset, such that there was no single value of the bar that could be associated with a given item. Following each study phase, a test phase of ten trials was presented in a random order, with the more recent item presented at the top of the screen for half of the trials.

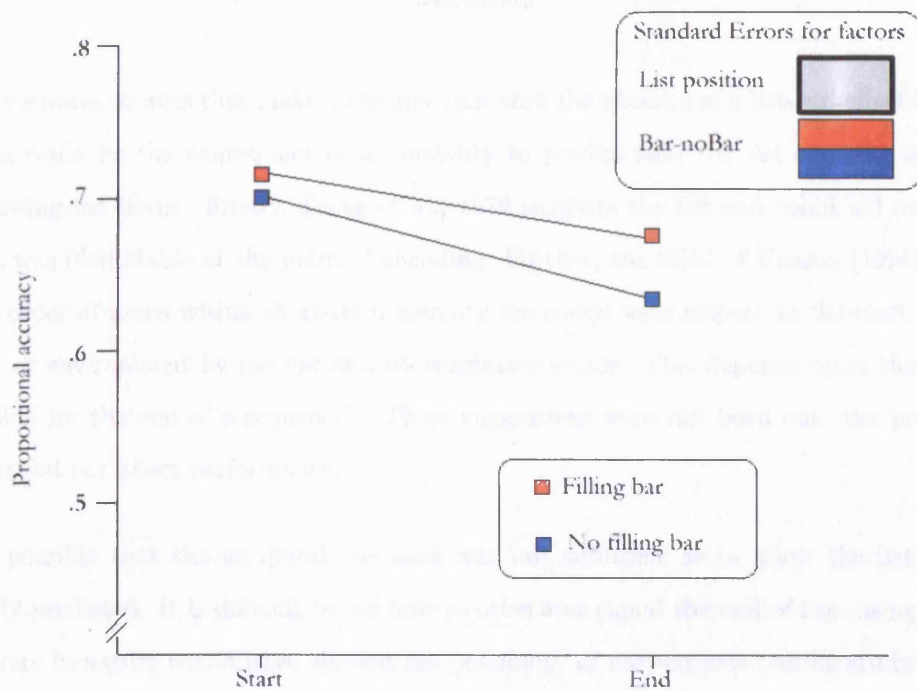


Fig. 2.13: JOR accuracy for Start and End items in presence and absence of filling bar.

Results

As before, the ten data points in every test phase was split into two bins, one for Start Pairs (defined as those containing targets 6 to 10) and one for End Pairs (with targets 15 to 20). This allows the derivation of four proportional accuracy scores: Start(Bar), Start(NoBar), End(Bar), End(NoBar). Overall performance was better in the Bar condition, with accuracy across JORs of .66 against .62. The critical issue is the effect the manipulation has on End items — whether expectation of the end of the list revives a recency effect. Figure 2.13 presents the relationship between presence of bar and study list position. Performance in the Bar condition is somewhat better than in the No Bar across both levels of study position, with performance more dissimilar for End items. A 2 x 2 ANOVA was used to analyse the main effects: presence did not have a significant effect on performance overall, $F(1,35) = .951$, n.s., whereas main effect of list position was borderline significant, $F(1,35) = 3.62$, $p = .065$. The specific prediction that End items would benefit from the presence of an indicator of the list end was assessed via a t-test, which revealed no significant differences between accuracy scores, $t(1,35) = 1.247$, n.s. This was contrary to expectation that list end might aid judgment on preceding items, were it only to be clearly anticipated.

Discussion

There are several sources that make a credible case that the absence of a list-end effect in the JOR paradigm could be the consequence of an inability to predict that the list end was approaching while viewing list items. Firstly, Tzeng et al., 1979 suggests the list end could aid memory, but only if it was identifiable at the point of encoding. Further, the SEM of Henson (1998b) suggests that the order of items within short-term memory are coded with respect to the start and end of their list or environment by the use of a bi-coordinate vector. This depends upon the “degree of expectation for the end of a sequence”. These suggestions were not born out: the presence of a filling bar did not affect performance.

It is possible that the temporal cue used was not sufficient as to allow the list end to be accurately predicted. It is difficult to see how to otherwise signal the end of list: using a cue that was discrete in nature would have allowed the possibility of participants pairing study items with their cues, and making judgments by recalling these associations. It could also be argued that the bar presented an extra perceptual load which harmed encoding and hid any facilitatory effects. One could argue from this that in ideal circumstances an expected list end would lead to a benefit for End items, and the instantiation of a Recency effect. For this to carry weight, one would need to demonstrate that performance for Start items was worse under the Bar condition; in fact, it was (non-significantly) better. This would require that the perceptual load from the bar be offset by a facilitatory effect applied across Start and End items; such an effect is beyond the current specification of these models.

This experiment suggests that applying the SEM to longer-term paradigms does not account for the patterns of performance found therein. This is not inconsistent with the claims made about the model, as it is constructed to account for short-term data, but it does limit its generalisability to lists exceeding span and the LTM range. It also has implications for an alternative account of temporal landmarks, as it suggests that landmarks only aid in reconstructing the “route” that follows, not precedes it. This will be taken up in Chapter 3.

General Discussion

The findings of the experiments reported in this chapter suggest that there is a durable Primacy > Recency effect in the study-test JOR paradigm. Experiment 1 first demonstrates this effect,

which was replicated in Experiment 2 where a number of aspects of experimental procedure were automated and the order of test pair presentation was factorially counterbalanced, in order to assess the predictions derived from the ratio rule used in temporal discrimination accounts. The replication of the finding over experiments and across modalities suggests that it is robust and reflective of genuine underlying psychological processes. This finding runs counter to claims made by models that draw on the timing literature, such as G. D. A. Brown et al. (2000), and is not consistent with the use of a dual-vector order code along the lines of Henson (1998b). It could be consistent with a reconstructive account wherein events in proximity to a temporal landmark are encoded alongside that information, making them easier to place in time.

Experiment 2 also provided several further findings that weigh against the temporal discrimination hypotheses. It allowed access to single-probe data, wherein the most recent pairs possess high temporal discrimination values, and found that such cases do not outperform pairs containing Start items; nor do those recent pairs show a pattern of performance in line with their temporal discrimination values. Indeed, across study positions and test positions, no relationship exists between temporal discrimination and accuracy of JOR. These provided stringent confirmation of the suggestions made in Experiment 1, both through its positional effects and lack of a rate manipulation effect, that temporal discrimination values are not driving order judgments. In particular, the lack of a relationship between performance and test position for Target 20 (see e.g. Figure 2.10), where differences in temporal discrimination values are very large, suggests that for typical cases, where ratios are rather lower (see e.g. Figure 2.11 for the values typically seen in this paradigm), the likelihood of this type of information contributing is low.

Experiment 3 provided further findings against the application of the SEM: it assessed the suggestion in Henson (1998b) that end coding may depend upon the degree of expectation for the end of a sequence, and found no effect of manipulating this expectation upon performance. The data suggests that at the timescales used here the end of list is used neither as a temporal landmark nor as a component of a vector code.

In addition to the positional effects investigated across these Experiments, Experiment 1 examined the role of modality in JORs in LTM. Findings which suggest better performance for enacted actions (McAndrews & Milner, 1991; Nilsson & Cohen, 1988) could be taken as evidence that action sequence have privileged access to temporal information. Alternatively, this may reflect a modality effect due to multiple or richer representations available when an item can be coded by

both verbal and non-verbal routes (Paivio, Rogers, & Smythe, 1968). The data shows that both enacted actions and representational line drawings produce better JOR accuracy, which is consistent with the dual coding account.

These findings are consistent with a location-based contextual reconstructive approach. The modality effects found in Experiment 1 are not readily explained by positional models or temporal discrimination models, but can be explained with recourse to the argument made in Johnson et al., 1993 that memory characteristics of individual items determine the degree to which those items can be contextualised. Richer representations may offer more opportunities for associating items with one another, or alternatively with an environment. For an example of the former, objects may be associated via rhyme or imagined along a visual journey. For the latter, item sequences may be represented as a set of short verbal lists or a set of visual scenes, denoting the start, middle and end of the sequence.

Reconstructive accounts of temporal memory are consistent with the finding that position of an item within a list affects temporal judgments, as these accounts stipulate the contextual status, rather than temporal distance or distinctiveness of an item, is crucial for determining its position, and a list constitutes one such context. One way in which such context is useful is the association of items with environmental features that themselves confer temporal information, including proximity to a temporal landmark, such as the beginning of a list. Examination of the accuracy for pairs shown in Appendix A reveals that accuracy for the first two items outperforms all other items. This may be suggestive of associative encoding of very early items with the temporal landmark of list start.

In summary, this chapter offers evidence against predictions based upon end-coding and the ratio rule. It is consistent with reconstructive accounts where the establishment of associations between items and between items and their environment is critical in enabling order judgments to be made. The use of temporal landmarks may play a part in this process, and the beginning of a list may operate in this manner. However, the superior performance at the start of the list could be the consequence of intrinsic positional factors, or the absence of proactive interference, or greater opportunities for rehearsal. I will explore these issues in greater detail in the following chapter, as well as the degree to which the primacy effect is the consequence of effortful, strategic use of information.

3. TEMPORAL LANDMARKS IN JUDGMENTS OF RECENCY

The results of Experiments 1–3 show an advantage for items from the start of the list when judgments of recency are made within a sequential study-test format. This effect applies across several modalities, although the more stringent procedure utilised in Experiment 2 only involved word stimuli. Within Chapter 2, I suggested that this pattern of results may be consistent with a reconstructive account wherein the start of lists is used as a temporal landmark. The purpose of this chapter is to expand upon that suggestion, beginning with a closer examination of what would characterise a facilitating effect of temporal landmarks upon JOR accuracy.

Temporal landmarks are events which possess useful temporal information that may assist memory judgments made on other events by deducing the relationship between them. In autobiographical memory, this may involve remembering that events have occurred before or after a key event for which the date is available. Although this implies temporal landmarks may effect judgments on antecedent events, this is not an example of a “temporal paradox” as defined to in Chapter 2; many temporal landmarks can be clearly anticipated, such as personal events including anniversaries, weddings, or celebrations of fixed events such as graduation, and public events such as elections, jubilees or timetabled policy changes. Regardless of the degree of expectation of temporal landmarks, events that precede it are, if they are to be fixed in autobiographical memory, rehearsed and reinterpreted subsequent to their encoding, such that information about subsequent events can be integrated into memory.

In LTM, however, it seems less plausible that temporal landmarks may be involved in judgments about antecedent events. There is not the opportunity for extensive rehearsal and reinterpretation of events, and the results of Experiment 3 suggest that regardless of expectation, this strategy is not naturally employed in list learning techniques. Rather, temporal landmarks at this scale may be best considered as the exercise of a simple associative mechanism wherein later items are encoded together with earlier information. If the results of the previous chapter are to be considered in this

vein, it must be established that the pattern of results squares with this formulation, and is not the consequence of a more parsimonious interpretation.

One explanation that is often advanced in the literature for superior memory performance of earlier items is that rehearsal facilitates memory, and has a greater opportunity to exert its influence for earlier items (Tan & Ward, 2000). This will be investigated in Experiment 4.

Another is that items from the beginning of a list benefit from the absence of items preceding them, preventing proactive interference or reducing the number of competitors that could feasibly fall in that position — an edge effect. This will be investigated in Experiment 5. This experiment also offers an opportunity to investigate a further aspect of the temporal landmark hypothesis suggested above: whether useful temporal landmarks cast their effect only towards subsequent items, or bi-directionally. A further explanation of primacy effects is that additional attention is geared towards earlier items which results in better encoding for these items; this is investigated in Experiment 6.

These investigations are vital to supporting the claim made that the primacy effect is evidence for temporal landmarks. The effect could merely be an epiphenomenon, in which case there is no need to posit the operation of temporal landmarks. Experiments 4 to 6 attempt to address these potential objections. They do so by (i) using stimuli that are difficult to verbally encode and hence to smoothly rehearse; (ii) investigate whether similar start effects can be introduced for positions preceded by items; (iii) manipulate the perceived efficacy of landmarks *after* encoding.

Experiment 4 - The role of verbal labelling and rehearsability

Active rehearsal improves item memory (see e.g. Mechanic, 1964). This simple and widely documented phenomenon often has implications for memory models. Some researchers have pointed to the role rehearsal may have in producing a primacy effect. Tan and Ward (2000) demonstrate that early items are rehearsed more often and recently than items from the middle of the list, and argue that primacy is itself the consequence of recency effects acting upon those recent rehearsals; they employ the ratio rule (Crowder, 1976) in doing so. Other researchers have also suggested that primacy is attenuated or removed under conditions where rehearsal is reduced (Howard & Kahana, 1999; Watkins, Neath, & Sechler, 1989). Under this view, primacy is not a phenomenon in itself,

but a mirage created by rehearsal. If this were the case it would cast doubt upon the proposal of a temporal landmark-based primacy effect.

A recent study by Avons et al. (2004) investigated the hypothesis that items at the start of the list tend to benefit because they have been rehearsed more recently. To minimise rehearsal they employed novel abstract visual stimuli which were difficult to verbally label. This followed an early study by Phillips and Christie (1977) in which similar stimuli were used in order to minimise rehearsal, and resulted in serial position curves which demonstrated no primacy effect. Like the Phillips and Christie study, Avons et al. revealed no primacy effect and a recency effect limited to the last item.

This would appear to challenge the interpretation of the previous experiments. It should however be noted that Avons et al used a different paradigm and different list length. Their study used single probe order judgments on pairs from adjacent serial positions, which may tap different mechanisms than more widely separated dyads. Study lists were composed of only six items presented sequentially, so the criticisms against generalising to longer spans and time periods that I previously outlined hold. The current paradigm has over three times as many items involved which are presented over a total span exceeding that of the Avons et al. experiments by fivefold. Consequently the extent to which the findings of Avons et al. generalise is unclear. An attempt must be made to assess the contribution of rehearsal to the primacy effect within the current paradigm.

Attempts to investigate temporal memory which use information which is minimally rehearsable, meaningful and impossible to form into narrative are problematic not just in terms of their broad ecological validity but because in doing so they disqualify the investigation of some of the well-specified candidate mechanisms, such as contextual association theory. If however the aim of the researcher is to discover, in Tzeng and Cotton's words: "When contextual cues are minimized, is strength [or temporal discrimination] sufficient to discriminate relative recencies of test items?" (1980, p.707), then attempts must be made to minimise these cues, even if one suspects that it is their involvement that enables normal human temporal memory.

This experiment employs a set of abstract pictures as stimuli in order to reduce the degree of verbal labelling in the task and hence reduce rehearsal. The stimuli are not the same as Avons et al.; that study used stimuli which were homogenous and extremely difficult to distinguish, and would be hard to make JORs at any level of accuracy within a list of this size. I instead

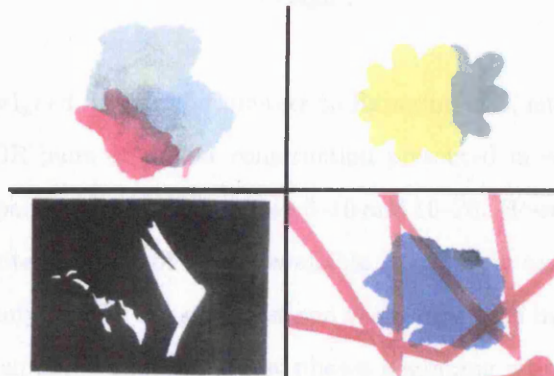


Fig. 3.1: Examples of Abstract visual stimuli used in Experiment 4.

employ a set of items previously used by Parkin, Bindschaedler, Harsent, and Metzler (1996), which although abstract have recognisable features and combinations of colour which seemed likely to make an impression, despite defying any obvious verbal labelling. An example of four such items is given in Figure 3.1. I am aware that this leaves this experiment open to charges that a preserved Primacy>Recency effect simply reflects the operation of such rehearsal that is available. To deal with this, data from a control condition employed in Experiment 3 will be employed to demonstrate the extent to which a change in performance reflects any kind of attenuation of the effect. This will also allow an opportunity to see whether less verbalisable stimuli leads to a generalised attenuation of performance. In Experiment 1, it was suggested that modalities that offered more routes by which items could be associated together or with an environment produced better performance across Start and End items. Here, such routes are less available, so one would expect a poorer performance overall. In summary, a contextual approach which relied heavily on item-item association and item-landmark association would predict poorer performance overall with a largely unaltered primacy effect.

Method

Materials and Participants

A total of 100 participants (62f, 38m; 19–59 years, M22.4) were recruited opportunistically from University College London campus. The program used was an adaptation of that used in Experiment 2, amended for the change in number of blocks and type of stimuli.

Design

This experiment was designed in a similar manner to Experiment 2, employing twenty-item study lists followed by the JOR pairs of similar construction presented in sets identical to those used therein — 5-separation pairs with targets between 6–10 and 16–20. However, only three blocks were employed due to the limited number of stimuli available. Items were sampled without replacement from a total pool of seventy-two for the study list and these were used in the subsequent test phase. As Experiment 2, participant k underwent test phases beginning with pair order set k , followed by $k+1$ and $k+2$ (cycling around to earlier items as appropriate). Due to the use of only three lists, the position of JOR pairs at test was not totally counterbalanced within-subject; this was achieved every ten participants.

Procedure

The general procedure is similar to Experiments 1–3. Participants were informed they would be presented with abstract pictorial stimuli which they should study for subsequent order memory testing afterwards. Participants were presented with three study lists which were random with respect to content, each followed by a test phase composed of ten test trials of the form described above. Timings of study list and test were identical to that previously employed. Unlike Experiment 2, participants initiated the transition to the test phase, and as per previous experiments participants initiated new study phases, in both cases by pressing any key.

Results

Correct responses per pair position were collated across lists for each participant, and backsorted into bins representing Start items (Targets 6–10) and End items (Targets 16–20). From this proportional accuracy scores were derived. Performance for Start pairs was higher, at .63(.18) than that for End pairs, .55(.16). This difference was analysed using a two-tailed paired samples t -test which revealed a significant difference, $t(99) = 3.502$, $p < 0.01$. This suggests JOR performance is superior for Start pairs over End pairs.

Although a Primacy>Recency effect is observed, it remains to be determined whether Primacy is unaffected by the use of poorly-rehearsable items. To do so, I employ data from an experiment

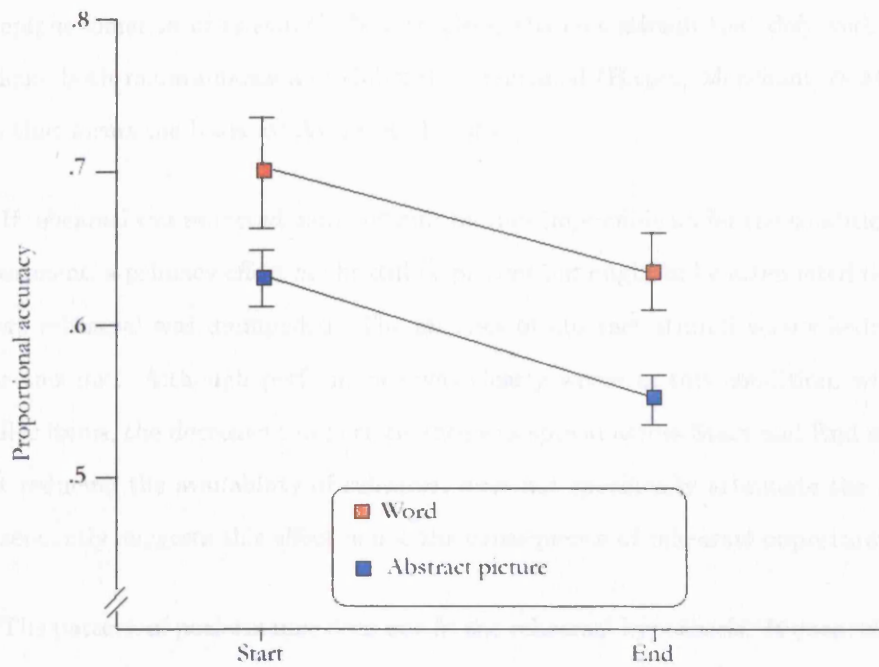


Fig. 3.2: JOR accuracy for word and abstract picture stimuli for Start and End pairs.

of similar duration (employing four blocks) that uses lexical stimuli — the control condition of Experiment 3. Stimulus type can effectively be seen as levels of rehearsal. The performance for different stimuli for Start and End pairs is shown in Figure 3.2. As in the previous chapter and all subsequent ones, the error bars denote standard errors. The lines denoting performance for each stimulus modality appear almost parallel. A 2X2 mixed model ANOVA shows a main effect of position $F(1,134) = 10.94$, $p = .001$, and type of material, $F(1,134) = 8.978$, $p = .003$, but no hint of an interaction, $F(1,134) = .085$, n.s.

Discussion

This experiment demonstrates that a Primacy > Recency effect exists for judgments of recency in a task using abstract pictures as study items. Such items are considered harder to verbally label and consequently less rehearsable. It also demonstrates that in a comparison between lexical stimuli and abstract picture stimuli, no interaction was observed between the stimulus type and position.

It is possible that some rehearsal was still available to participants, as this study did not employ stringent preventative measures such as verbal overshadowing, and the stimuli were not as impoverished as that used in other studies (Avons et al., 2004). As such, the preservation of

a Primacy>Recency effect does not in itself offer a powerful refutation to the argument that it is an epiphenomenon of rehearsal. Nevertheless, abstract stimuli that defy verbal labelling renders difficult both maintenance and elaborative rehearsal (Hagen, Meacham, & Mesibov, 1970); it is this that forms the basis for Avons et al.'s study.

If rehearsal was rendered more difficult but not impossible under the conditions presented in this experiment, a primacy effect might still be present but ought to be attenuated relative to conditions where rehearsal was unimpeded. The analysis of abstract stimuli versus lexical stimuli does not bear this out. Although performance was clearly worse in this condition, with less meaningful, similar items, the decrement in performance was spread across Start and End items. This suggests that reducing the availability of rehearsal does not specifically attenuate the primacy effect, and consequently suggests this effect is not the consequence of rehearsal opportunity.

The pattern of performance does not fit the rehearsal hypothesis. It does offer some support for the richness of coding hypothesis wherein the availability of different types of information assists the coding of items together or with their environment. While the pattern of performance across Start and End items is similar across modalities, performance for word stimuli is stepped above abstract pictures. This may suggest that processes that operate across positions are less accurate for abstract stimuli. This is consistent with the richness of coding hypothesis, where the coding of sequences of items or the blocking of items into loose bins of items (such as first set, middle set, end set) is likely to be useful across all positions. The results are consistent with a hierarchy of modalities, where those that consist of dual representations offer more opportunities for associative coding, verbal-only representations offer fewer and meaningless abstract visual stimuli still fewer, by virtue of the absence of useful mnemonic associations that can be made between such items.

Experiment 5

Experiment 4 suggests that the Primacy>Recency found in this JOR task is not the consequence of rehearsal of earlier items. The suggestion that rehearsal is a contributing factor does not carry a great deal of weight, given how levels of rehearsal (assessed through comparing modalities which differ in their ease of verbal labelling) do not interact with position. Another explanation of Primacy effects that undermines the Temporal Landmark/contextual association account is that earlier items enjoy a relative advantage due to the lack of Proactive Interference (PI; Keppel & Underwood, 1962). PI is the reduction in memory performance for items, due to the interfering effects of items which precede it. Alternatively, primacy could be explained as a consequence of “the inability of the terminal item to be involved in a transposition in more than one way because there are no adjacent items beyond the end of the list.” (Lewandowsky, 1999, pg 436). The latter phenomenon is typically termed an *edge effect*; the term may be equally applied to the PI account — both accounts specify that the advantage is an epiphenomenon of having no items to one side of it. A recent commentary on G. D. A. Brown’s unpublished SIMPLE model suggests that the full model may account for primacy effects as a consequence of a sparser density of competitors at the beginning of the list (Avons et al., 2004, see pg 869).

In summary, an edge effect may inflate performance at terminal positions and obscure the order memory effects of genuine interest. This confound may be circumvented by introducing a temporal landmark at other points in the list and investigating how performance alters as a consequence: attempting to instantiate a Primacy effect at a position other than the true start of the list. This is the purpose of Experiment 5. In this experiment, studied material is presented in extended lists, which are interrupted either by a filler item indistinguishable from its neighbours, or a temporal landmark denoting the “Start of New List”. If performance following the temporal landmark enjoys a lift, relative to the filler condition, this suggests the Primacy effect in JOR judgments cannot be credited solely to edge effects as the items following this landmark would be equally subject to PI or errorful transpositions from neighbours. It suggests, instead, that some hierarchical grouping mechanism exists over-and-above memories for individual items and that this mechanism can facilitate judgments of recency. Note that the *timing* of presentation of items and testing of items is matched. If time was the main determinant then a null effect should be found.

An additional opportunity this experiment offers is to investigate whether landmarks which prove useful to participants lead to facilitated performance on items that fall before the landmark.

I earlier suggested that part of the temporal landmark signature amassed thus far is a facilitatory effect only for items falling after the landmark; this experiment offers a further opportunity to investigate this claim.

Initial piloting of this experiment used an extended list composed of two twenty-item lists back-to-back. Performance turned out to be extremely poor, and it was decided instead to use shorter lists of sixteen words back-to-back separated by the filler/landmark. As a consequence, this experiment deviates from the pair formation employed in all other experiments, using JOR pairs of 4-separation, for example 2–6.

JOR pairs were composed as if the extended list really were two discrete lists; pairs did not “cross-over ” the temporal landmark/filler. The reason for this is clear: should items cross-over, the temporal landmark is really nothing of the sort, merely a salient item. For it to act as a temporal landmark, it must usefully demarcate a temporal stage, in the same way as a true list start does.

Method

Materials and Participants

A total of twenty participants (19 – 29 years, M21.12) were recruited opportunistically from UCL campus. All participants had English as a first language. The program used was an adaptation of that used in Experiment 1, amended for the change in number of blocks and type of stimuli, as well as the composition of study lists, JOR pairs and test phases. This experiment was carried out earlier than Experiment 2 and 4 and consequently does not share the design components of factorial counterbalancing, automatic test-phase transition or automatic trial transition; on these matters they are identical to Experiment 3.

Design

This experiment employed a 2X4 within-subjects design, where one factor (presence of landmark) varied across blocks and the other (original study position of test items) varied within each block. The task was composed of 4 blocks. Study phases involved the presentation of a super-list formed of two sixteen-item sub-lists, lists I and II, presented back to back with one item intervening. This

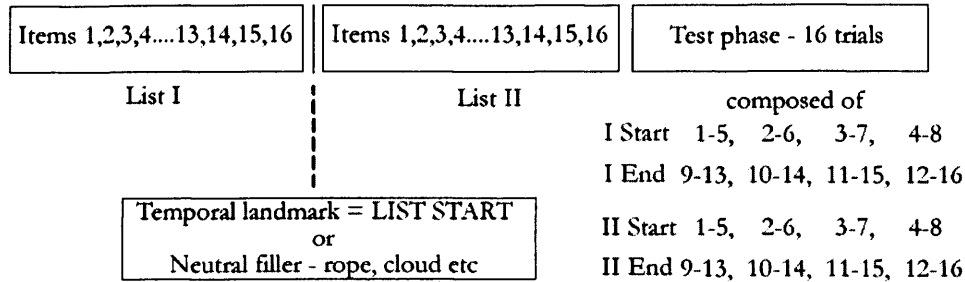


Fig. 3.3: Composition of block: study list, intervening item, study list and test phase.

item was either a neutral filler item (NF) or temporal landmark (TL). The study items and NF were drawn without replacement from a pool of words from the MRC psycholinguistic database. All words used were concrete nouns, matched for familiarity, concreteness and imaginability, as dictated by Paivio norms (Paivio, Yuille, & Madigan, 1968). The temporal landmark was always the alert "Start of New List". Half of the participants received the TL on Blocks 1 and 3, the other half on Blocks 2 and 4. The test phase was composed of eight trials that corresponded to the first sixteen-item sub-list and eight trials that corresponded to the second sub-list. These trials were not blocked but randomly intermingled. The composition of the pairs presented in each trial differed from previous and subsequent experiments in that they were composed of items with a smaller separation of four items: 1-5, 2-6, 3-7, 4-8, 9-13, 10-14, 11-15, 12-16. This is necessary to prevent overlap and redundancy in sixteen-item lists. For clarity these will be referred to in their entirety (1-5) rather than by their target (5). This is depicted in Figure 3.3.

Procedure

The procedure is very similar to the previous experiments. Participants were informed that they would be presented with a series of lists of verbal stimuli, and after each list would be tested for order memory. They were informed that some lists would be cleaved by a message alerting that a new list was starting, but that this subdivision should not prevent them from attending to the items as they had been. Participants were then presented with a study phase of 33 items, two sixteen-item sublists between which the NF or TL was presented. After each study phase participants made sixteen JORs on pairs from before and after the intervening item.

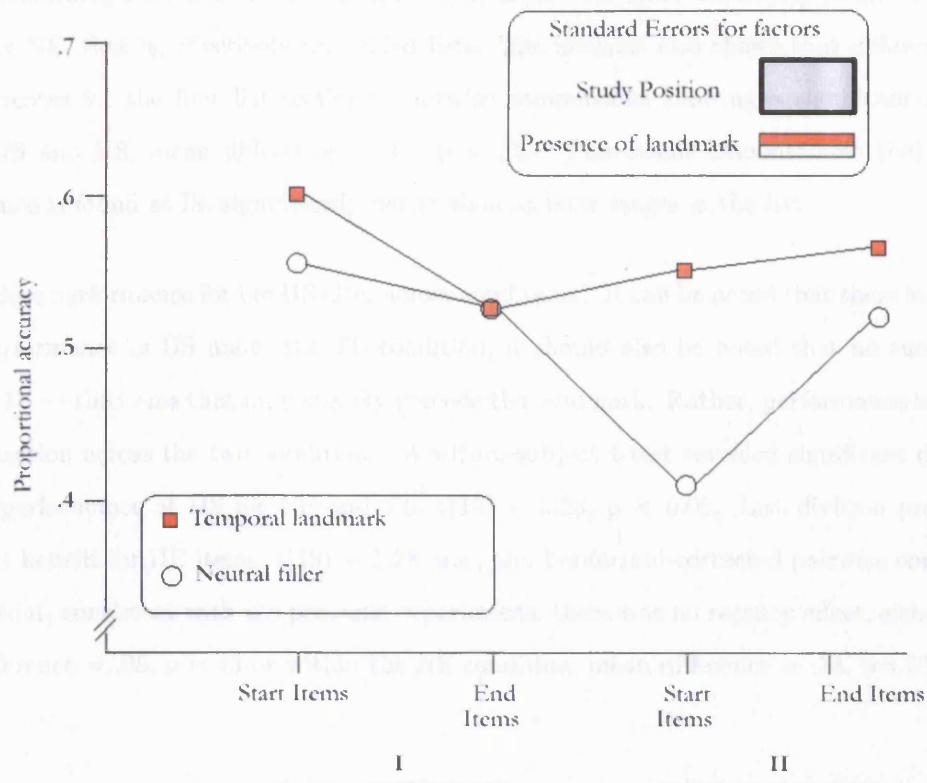


Fig. 3.4: JOR accuracy for list positions in presence and absence of mid-way temporal landmark.

Results

There were thirty-two items that were placed into JOR pairs, and these will be labelled items 1–32 for the purpose of this analysis, such that the first item in the superlist is 1, the first item following the intervening item is 17, and the last item is thirty-two. Data was backsorted into eight bins: List I Start items (IS; 1–5, 2–6, 3–7, 4–8), List I End items (IE; 9–13, 10–14, 11–15, 12–16), List II Start items (IIS; 17–21, 18–22, 19–23, 20–24) and List II End items (IIE; 25–29, 26–30, 27–31, 28–32) for NF and TL conditions. I wish to establish whether there is some form of Primacy effect that is common across groups. This can be established by comparing IS to all other points in the list, summing across Filler conditions. This experiment principally aims to demonstrate that following a temporal landmark, midway items receive a lift in performance. This is achieved by investigating performance across Filler conditions, particularly at IIS. Mean performance for the TL condition was .70(.186) whereas for NF it was .63(.204). Figure 3.4 shows the performance at different positions across conditions. A 2 x 4 ANOVA revealed significant main effects of both Filler, $F(1,19) = 20.06$, $p < .001$ and of original study position, $F(1,19) = 3.747$, $p < .05$.

This demonstrates that lists containing the TL division were more accurately judged than those containing NF, that is, effectively undivided lists. The analysis also shows that differences exist between scores for the four list sections: pairwise comparisons showing a significant difference between IS and IIS, mean difference = .12, $p < .05$. This result demonstrates that the best performance is found at IS, significantly better than at later stages in the list.

How does performance for bin IIS alter across conditions? It can be noted that there is markedly better performance in IIS under the TL condition; it should also be noted that no such pattern exists for IE — the items that immediately precede the landmark. Rather, performance is identical at this position across the two conditions. A within-subject t -test revealed significant differences between performance at IIS for NF and TL, $t(19) = 2.23$, $p < 0.05$. List division provided no significant benefit for IIE items, $t(19) = 1.28$, n.s., and bonferroni-corrected pairwise comparisons revealed that, consistent with the previous experiments, there was no recency effect, either overall, mean difference = .08, $p = .43$ or within the NF condition, mean difference = .14, $p = .20$.

Discussion

This experiment demonstrates superior performance for items that follow a temporal landmark which falls mid-way within a continuous list. Superior performance for items from the beginning of a list can be interpreted as an edge effect, whereby a relative absence of PI or fewer neighbours to afford errorful transpositions lead to better performance. Effects that occur mid-way in a list are not open to this interpretation. They suggest that rather than an edge effect, these effects may reflect the association of items with a temporal landmark which offers useful temporal information.

It is difficult to directly assess the relative effects of the primacy effect displayed in List II following the inserted landmark, as the primacy effect can be observed relative to a marked deterioration of performance in the control condition. This is presumably due to fatigue due to the very long lists involved in this experiment, which may be interacting with the smaller item separation of recency pairs dictated by the experimental design; Experiment 1 demonstrates that JORs are easier when separation is greater.

Given this difficulty in direct comparison, what other aspects of the evidence may suggest that this effect is best characterised as a landmark effect? Perhaps the clearest support is the fact that the experimental manipulation has a tightly focused effect upon performance on list items.

Performance on List I is similar across conditions, and critically, IE is identical across conditions. The effect of the temporal landmark presence is unidirectional, facilitating judgments only on those items following it - those in position IIS. This fits the signature established in previous experiments, and is consonant with our intuitions about the operation of temporal landmarks. In Experiments 1–4, events following list start, a potentially useful temporal landmark, enjoy greater accuracy, whereas those preceding list end, a similarly useful landmark, do not, even when the onset of the landmark is predictable. Associating events with a landmark that has occurred previously prevents no temporal paradox, requiring no special mechanism to occur. The unidirectional effect of the inserted landmark in this experiment is consistent with this signature, and augments it by presenting a case where a landmark that is having some facilitatory effect, and is placed before some items and after others, only confers its facilitatory effect on those that fall after.

In summary, this experiment demonstrates a boost in order memory for items that follow a landmark which confers temporal information, relative to a neutral filler item. This effect is confined to the items following the landmark, rather than aiding those prior to its presentation. This suggests that temporal landmarks have an effective independent of whatever advantage is offered by dint of having no preceding items.

Experiment 6

It is possible that a salient event within a list bestows extra attention and effort upon the items that follow, which could lead to better performance regardless of whether the event is acting as a temporal landmark. The results of Experiment 5 do not support this hypothesis, as the benefit following the landmark item did not seem to channel resources away from other stages of the learning phase, as performance was as good or better. In order to discount this possibility more forcefully it is necessary to adopt an approach where changes in performance can be achieved by manipulating conditions post-encoding. An example of this is found in C. J. Anderson's (2005) investigation into autobiographical memory. He found support for the claim that temporal landmarks rather than superior encoding were the source of calendar effects by showing that when memories were cued in the context of a temporal prompt, more memories were recalled from the calendar boundary periods than when the prompt was absent. Here I adopt this approach in a manner appropriate for my paradigm and timescale.

This experiment will essentially manipulate the perceived utility of temporal landmarks, in order to investigate whether superior performance for items following the temporal landmark is preserved when the participant is presented at test with little incentive to use the temporal landmark. This manipulation is effectively investigating the degree to which the primacy effect is the consequence of strategy use at retrieval or automatic processes at encoding. Temporal landmarks ought to involve some differential processing at encoding (the association of an item with the landmark) but this information should be conditional and subject to the perceived utility of that information at retrieval; should a participant decide that the landmark was of little use (as if times scribbled onto index cards were later discovered to be derived from a faulty watch) then this information may be minimised or discounted within the inferential process occurring at retrieval. Previous experiments have suggested that JORs in LTM involve a degree of intentional encoding (Naveh-Benjamin, 1990) and more recent evidence suggests strategic encoding may contribute to real-life instances of order memory (Schmitter-Edgecombe & Simpson, 2001). This experiment intends to investigate whether landmark use forms one of these intentional strategies.

This experiment will, like all previous ones, supply participants with a study list that begins with a clear (Start) temporal landmark. Prior to this all participants encounter a set of items similar to the study items, having been informed to make perceptual judgments upon these and not to worry about their recall. After the study list, participants under the experimental condition are

informed that the JORs they are to make will be upon items from before and after the temporal landmark, effectively discounting its usefulness and so discouraging its use. Importantly, this manipulation does not occur - experimental and control groups both undergo test phases composed of items following the Start of list landmark; groups only differ in terms of their instructions.

Under normal circumstances, when an item in a JOR pair cues the memory that it was associated with the Start of list landmark, that information is often sufficient to make accurate judgments, as that item cannot (or is highly unlikely to be) the more recent. However, if any of the twenty previous items may be included in the JOR pair, this information is no longer sufficient, and successful retrieval of memory information about the other item is necessary. Moreover, as previous experiments suggest that items preceding a landmark do not appear to be retrospectively coded with that information, and given that in this situation participants will not be attempting to do so (as they are not expecting any memorial demands to be put upon these processed stimuli) it is not clear that subjects would attempt to employ the landmark information even in a two-step “*x* before landmark” , “*y* after landmark” strategy. In any case, given their belief that the test phase will contain JORs composed of items from after and before the landmark, it is plausible that participants will not employ landmark-type strategies and rely instead on other sources of information, denying them the facilitation normally observed for items following the landmark.

If temporal landmarks represent one information source in a reconstructive process, alongside other information such as association of items with one another or broadly as sets associated with a background context, this manipulation should lead to an attenuation of the primacy effect as participants shift from relying on this strategy to other sources of information which are not as exacting, as only temporal landmarks offer definitive temporal information.

Method

Participants and Materials

One hundred participants formed the opportunity sample for this study. Mean age was 24 years (age range: 18–60 years). All participants had normal or corrected normal vision and were fluent in the English language to control for the possible confound of language knowledge. The experiment was conducted using a Visual Basic program on a standard PC, with keys “X”, “?”, “T”, and “N” clearly labelled for use in responding.

Design and Procedure

Participants were randomly assigned to either a Control or Experimental group, which were characterised by the instructions given prior to the retrieval stage of the experiment. The dependent variable measured was participants' accuracy of recency judgments. I predicted that in the control condition, a Primacy>Recency effect would be observed, but that in the experimental condition performance on Start items would be significantly lower and may result in a negation of the Primacy>Recency effect in that condition. The experiment consisted of a single block, as it could not be repeated due to the surprise nature of the instructions in the Experimental condition. Each block was composed of a Dummy task phase, a Study phase, and a Test phase. The Dummy task phase and Test phase were preceded by instruction screens. Stimuli from the Dummy task phase and Study phase were words randomly drawn without replacement from a pool of forty words selected from the MRC psycholinguistic database; this pool contained an equal amount of one-vowel and two-vowel words.

Dummy task phase — Vowel Counting. This first phase consisted of a vowel counting task wherein participants had to make responses on the basis of the number of vowels found in twenty words presented to them on screen. The words were presented serially at a rate of 2.5 seconds with an inter-item separation of one second. Participants were instructed to press the 'X' key if the word contained one vowel and press the '?' key if the word contained two vowels. The data from this task were not recorded or analysed.

Study phase. In this phase twenty words were presented at the same rate and separation as Experiment 5. The study phase followed on the heels of the dummy task, separated only by the temporal landmark announcing the start of the memory study list. This is displayed in Figure 3.5.

Test phase. This final phase consisted of ten judgments of recency made on pairs of a similar composition to those used in Experiments 2– 4, namely, items 1–6, 2–7, 3–8, 4–9, 5–10, 11–16, 12–17, 13–18, 14–19, 15–20. As with those experiments pairs will be referred to be their target number (e.g. pairs 3–8 and 4–9 are Targets 8,9). These were presented on screen one above the other with the target on top for five of the ten trials. Participants were instructed to press the 'T' key if they judged the top item to be more recent and the 'N' if the bottom item. This experiment employed a counterbalancing of the order of test trials across participants, such that participant

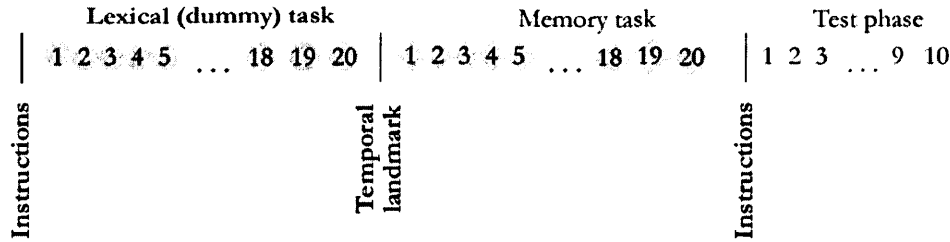


Fig. 3.5: Depiction of lexical decision making task and study task.

1 received the trial pairs in a sequence identical to Set C1 from Appendix B, participant 2 Set C2 and so on.

Instructions. The initial instructions alleged that the experiment was interested in task switching, and that two tasks would be involved in the experiment. They explained how to respond in the vowel counting task, and that it would last for around twenty items. They then stated that following this a message on screen would alert the beginning of the next task — the memory task — wherein they will study words which they must later judge the relative position of in a pairwise fashion. The second set of instructions differed across groups. The control condition were merely informed to make judgments of recency using the appropriate keys. The experimental condition instructions began with the following text: “This is the second task, but we must admit we mislead you. We are going to ask you to make judgments about when words you saw occurred, and this includes the words you saw in the first task (vowel counting).” The instructions were otherwise identical.

Results

The data was collated into bins of Start items (Targets 6–10) and End items (Targets 16–20). The mean number of correct responses for each type of judgment is seen in Figure 3.6.

It can be noted that performance is generally poor and close to chance, poorer in fact than that achieved in Experiment 4, where the stimuli was non-verbal and hard to memorise. Also notable is that performance for Start Items is higher in the Experimental condition than the Control condition, contrary to predictions, and that in both cases there is little difference between Start and End performance.

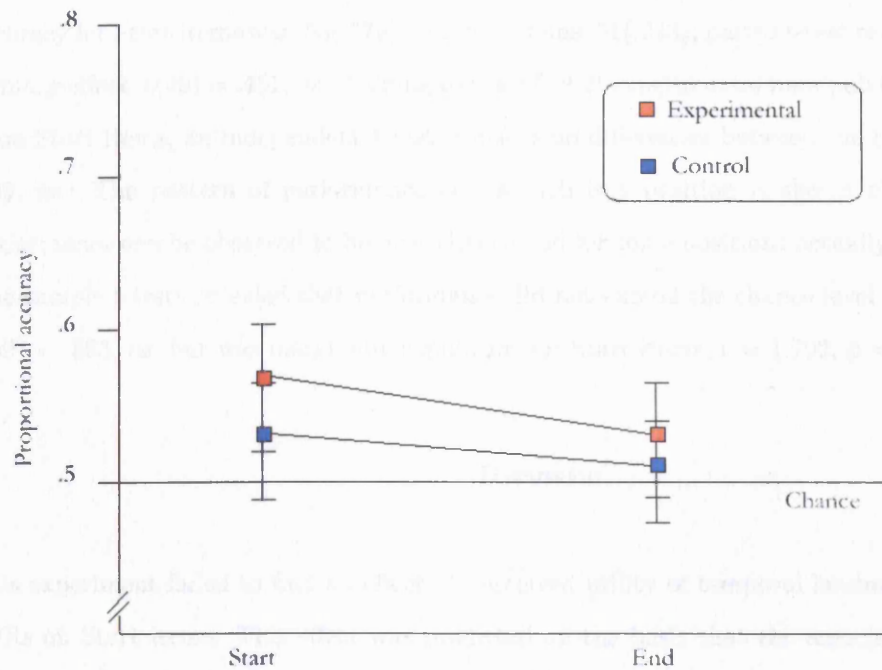


Fig. 3.6: JOR accuracy following lexical decision modification when landmark utility is rendered uncertain versus control condition.

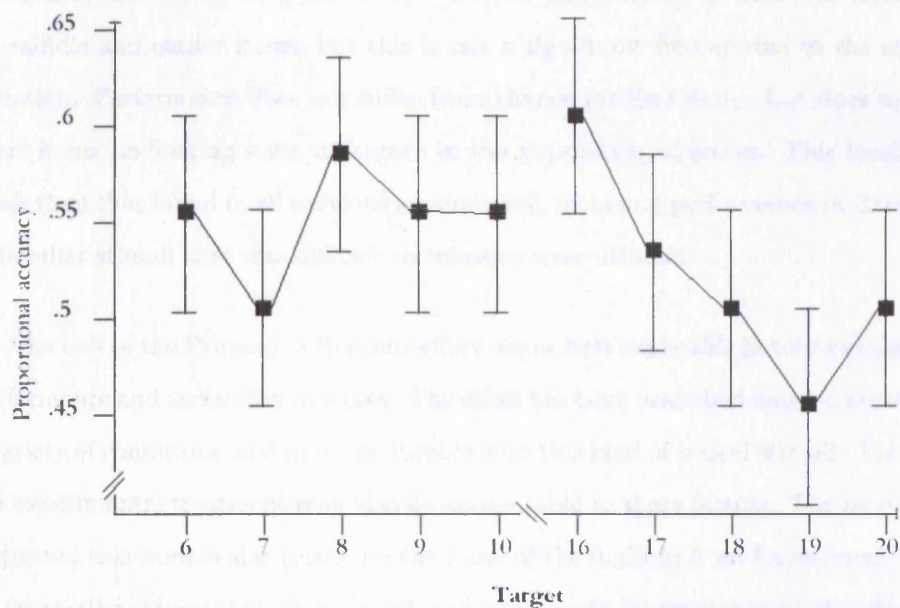


Fig. 3.7: JOR accuracy for each target across conditions.

As an initial step the data was analysed to establish whether this experiment replicated the effect of previous studies of Primacy>Recency in its control condition. For this condition, where accuracy for Start items was .53(.279), and End items .51(.243), paired t-test revealed no significant primacy effect, $t(49) = .451$, ns. Turning to the effect of experimental manipulation on performance upon Start items, an independent t-test revealed no differences between the two groups: $t(98) = .399$, ns. The pattern of performance across each test position is shown below in Figure 3.7. Performance can be observed to be near chance and for some positions actually falls below chance. One-sample t-tests revealed that performance did not exceed the chance level of .5 for End items, $t(99) = .883$, ns, but was marginally significant for Start items, $t = 1.792$, $p = .076$.

Discussion

This experiment failed to find an effect of perceived utility of temporal landmarks on accuracy of JORs on Start items. This effect was predicted on the basis that the association of single items with a temporal landmark such as the beginning of list provide an easy and accurate method to performing such judgments, obviating the need to make a comparison between both items; if this route was perceived to be useless, other, less accurate strategies must be deployed. There is no evidence here that this is the case. This experiment was also the first to fail to find the Primacy > Recency effect described previously. Overall performance is worst for later items and better for middle and earlier items, but this is not a significant finding due to the scores showing high variation. Performance does not differ from chance for End items, but does marginally differ for Start items, indicating some difference in the population of scores. This level of performance is lower than that found in all previous experiments, including performance in Experiment 4, wherein unfamiliar stimuli that was difficult to rehearse were utilised.

The lack of the Primacy > Recency effect seems best explicable in terms of the overall poverty in performance and variability in scores. The effect has been described under a number of modalities in a variety of conditions, and appears durable with this kind of lexical stimuli. The lack of an effect of the experimental treatment may also be accountable to these factors. The power calculations that suggested this sample size (made on the basis of the findings from Experiment 1) were predicated on far smaller sigmas than those found, and expecting a far greater level of performance that would allow for a drop in performance of around .07 (to bring Start performance roughly in line with End performance).

Why is performance so low? One possibility would be that the single block design prevented any opportunity for training to attain some level of competence. The plausibility of this can be assessed by examining the change in performance from first and last block in Experiment 4. The overall performance there did increase from .59 to .61 from Block 1 to Block 3, but this was not significant, $t(99) = .983$, ns. It appears that while the lack of acclimatisation might have played some role, it is insufficient to account for the change in performance.

Although the poor scores cannot be attributed to the experimental condition, as performance was similarly poor in the control condition, the use of a dummy task was common to all conditions. It seems highly likely that it is this that has affected performance in some way. Participants were expected to attend to forty words, and remember details about the second set of twenty. It may be that the first set of stimuli are directly interfering with memory for the second set. This must be assessed in light of Experiment 5, where nearly as many items are presented, with performance on the second set at .69 when a landmark was in place.

A further possibility is that the dummy task itself, rather than the dummy stimuli, interfered with performance. The task switching literature (see e.g. Monsell, 2003) details numerous instances where involvement in multiple tasks results in impaired performance on one or more tasks. Waszak, Hommel, and Allport (2003) demonstrate that a single task switch can impair performance on the subsequent task, particularly in instances where it involves similar stimuli. This experiment may have resulted in such conditions as a consequence of incorporating a lexical decision task followed by a memory task on the same type of stimuli. This was a necessary component of the experiment, as using dissimilar stimuli across tasks such as items of different modality would have made the experimental manipulation ineffective, as it would have been obvious to participants that judgments were being required of the post-landmark items only. Such carry-over effects are most deleterious immediately following the task switch, meaning that Start items would suffer more than End items, making the attenuation/elimination of the Primacy > Recency effect explicable.

It should be stressed that even had the experiment not suffered from a lack of replication of the basic finding of interest (primacy effect), the paradigm could be considered precarious. As mentioned in the introduction, for the manipulation to have an effect it is essential that participants believe in it, both initially and for at least some amount of the test phase. Should they be skeptical from the off, this would cast no light on whether landmark effects have an intentional, top-down component.

Regardless, this experiment has failed to show the predicted effect of perceived landmark utility, and is unable to address whether the superior performance following a landmark is due to enhanced attention/encoding or due to explicit use of landmark information.

General Discussion

The findings of the experiments reported in this chapter suggest that the primacy effect found in judgments of recency is solely attributable neither to the role of rehearsal nor that of absence of PI. The effect of manipulating perceived landmark utility after encoding was investigated but no effect was found. The results of Experiments 4 and 5, together with 1 and 2, support the use of the start of list as a temporal landmark that aids performance on those items that immediately follow it. Such landmarks do not provide any benefit for items that precede it, neither when explicitly framed as the start of a new list (Experiment 5) nor in the case of the end of list (see Experiment 3). This implies that items following a temporal landmark may be encoded with useful temporal information from that landmark. This has implications for several theories.

Some accounts of primacy and recency effects suggest that these effects are due to intrinsic advantages offered by items with fewer neighbours, due to less interference or fewer candidates for errorful transpositions, or the onset of fatigue later in studying lists (see Lewandowsky, 1999, and the characterisation of SIMPLE given in Avons et al., 2004). This argument does not hold in the face of the results of Experiment 5. Here an advantage follows a temporal landmark even if it does not fall at a natural edge of a list. This suggests it is the landmark, rather than the fact that items fall at an edge, that may be responsible for superior performance at these positions.

Other accounts suggest that primacy effects are an epiphenomenon due to greater opportunity for rehearsal (Avons et al., 2004). The repeated findings of superior performance for earlier items, even under conditions where the opportunity for rehearsal is greatly reduced, suggests that this is an insufficient characterisation of the primacy effect in the JOR task. Rehearsability, and the routes open for association between items, does appear to support accurate JORs, but this appears largely independent of the primacy effect. As a consequence, primacy effects for order in LTM do not fit the account of primacy as a consequence of rehearsability, and such accounts must either attempt to describe STM or present more compelling evidence.

Experiment 5 presents a set of results that contribute to an intelligible signature of LTM temporal landmark effects. Specifically, it demonstrates that the presence of a landmark effects

items that follow it, rather than precede it. Previous experiments did not demonstrate effects for items preceding list end, but this could be characterised in terms of absence of a landmark. This experiment demonstrates that a present landmark confers an advantage on surrounding items that is unidirectional. One implication of this is that even at list lengths shorter than those typically used within these experiments — 16 items in List I — recency effects are not observed.

The aim of Experiment 6 was to investigate whether the effect of list start upon JOR accuracy for Start pairs was due in part to more effortful, top-down processes. This would be consistent with an account that considered the use of temporal landmarks as part of a reconstructive, inferential process, involving the weighing of evidence according to its utility. The failure of this experiment to reproduce the effects found previously, and the poor pattern of performance found throughout the task, prevent it from speaking decisively to this issue.

The results of these experiments are generally at odds with the temporal discrimination theories of G. D. A. Brown (e.g. G. D. A. Brown & Chater, 2001). These predict a graded recency effect due to better discrimination of more recent items, so an isolated primacy effect is not in keeping with their theory, and would need to be explained away by an appeal to other factors. Experiment 4 provides evidence that the primacy effect is not the consequence of superior rehearsal at the beginning of the list. An issue outlined in the general introduction warrants reflection here. Even if displaced rehearsals are continuing to occur, their presence does not offer an easy way out for proponents of temporal-based order judgments. Later rehearsals should if anything serve to muddle the sense of temporal position, as the item would be re-encoded with a temporal code based upon the oscillator readings at that time, not the time of the original event¹. That the temporal landmark can have its effect irrespective of its position in the list (Experiment 5) supports the use of entirely non-temporal information in making order judgments. The G. D. A. Brown model appears to fall into the camp of characterising primacy effects as an edge effect; if this proves to be true, Experiment 5 challenges this component of the model.

The pattern of results obtained in this and the preceding chapter suggest that serial recall and relative recency tasks show a different pattern of performance, which may imply reliance on different kinds of order representations. Greene, Thapar, and Westerman (1998) suggest that contrary to serial recall tasks, in the judgment of recency “there is no need to reconstruct the entire list on each test trial....The subject would then try to infer relative recency based the information contained in the two traces. These inferences may be based on the contextual information available

¹ An equivalent criticism was made by Tzeng (1976) against the “tape recorder model” (Murdock, 1962).

in the trace and/or the sheer amount of information contained in the trace if the subject assumes that such information may decay over time” (pg 256). The findings reported here may speak to the common coding assumption, as they present a pattern of evidence at odds with the conventional bowed curve found in serial recall investigation; this would require further research on the serial position task at the longer time intervals involved in these studies to establish whether the pattern of evidence is the outcome of different representations employed by different tasks, or different representations/strategies employed at different timescales.

The evidence from this chapter is broadly compatible with the contextual reconstructive theories of Friedman (1993) in their suggestion that temporal judgments are often made with the assistance of temporal landmarks. These theories are often focused on autobiographical memory and memory for public events, but Friedman (2001) had suggested the possibility that primacy effects within list-learning paradigms could be considered under this framework. The investigation of this suggestion forms one of the novel aims of this thesis. The findings described above are supportive of a role for temporal landmark, but also suggestive of other mechanisms that may operate in the judgment of recency task.

The effect of inter-item separation of JOR test pairs described in Experiment 1 and previously (Tzeng & Cotton, 1980; Yntema & Trask, 1963) are consistent with positional models and distance-by-proxy accounts of order memory. That is, these effects may be reflective of more distinctive positional codes, or the comparison of memory traits such as memory strength (Hinrichs, 1970) or generalised strength (Dennis & Humphries, 1998) when discrepancies are clear and available.

This separation effect was independent of the primacy effect described in Experiment 1 (and later replicated in Experiments 2–5). This suggests that this effect is underpinned by a separate mechanism, which I suggest is the operation of list start as a temporal landmark. The signature of the temporal landmark effects I am describing is facilitated performance for items immediately following the landmark, in the absence of facilitation of preceding items. This effect may occur wherever the landmark is within the list, as long as it is able to confer useful temporal information.

How might such temporal landmark effects be achieved? One suggestion is that the process may be akin to Tzeng and Cotton’s (1980) study-phase retrieval theory, wherein current events cue or elicit prior events that are coded alongside the current event. The start of the list represent one such prior event, albeit one that is extremely temporally informative.

A third effect which was independent to both positional effects was the role of modality in Experiment 1, where richer representations with multiple routes of encoding led to better performance across the list. I have argued that this effect may be considered to reflect the ease of association of items to one another or to their context, either in terms of arbitrary blocking of the stimuli by the participants, or association with positional bins. This is supported by Experiment 4, where the opportunity for association was decreased by the use of unmeaningful stimuli, resulting in poorer performance across the board but a preservation of the primacy effect.

In summary, the data suggests that temporal order judgments in LTM may involved multiple processes relying on the following sources of information:

1. proximity to a previous temporal landmark
2. distance or positional information conferred when items are separated sufficiently
3. association of item-item (chaining), item-context or item-positional bins (positional models), which is supported when richer representations offer more routes to make these associations

This account mirrors recent appeals for a synthesis of chaining and positional accounts of STM. Murdock (2005) suggests neither such models account for the data in STM, and clearly these models alone do not succeed for LTM either. Murdock suggests some models that attempt to do so, but it seems unlikely that these will prove useful for accounting for LTM. One example, the network model (N. Burgess & Hitch, 1999) prohibits its extension into LTM, and Murdock's preferred approach of multiple-item association accounts (Murdock, 1995, 2005) now emphasises the power-set model, which relies upon each item being associated "not with the prior item, but with all the prior items and associations formed to date" (Murdock, 2005, pg 262), which seems less plausible for increasingly longer lists. The particular role that temporal landmarks may have in LTM also requires a model willing to incorporate such effects; at present none are available.

4. THE ROLE OF LIFETIME PERIODS IN THE TEMPORAL ORGANISATION OF REMOTE EVENTS

In the previous two chapters, experimental work examined temporal judgments in long-term episodic memory, in order to assess the contributions of internal, dedicated temporal information versus item-context associations. In this chapter attention will be given to the ability to make temporal judgments about a different kind of memory, autobiographical memory (AM). The same issues will be addressed in AM as in LTM: does information intrinsic to the memory aid temporal judgments? Are such judgments made with the assistance of contextual associations to information outside of the memory trace?

A recent model has suggested that temporal judgments may be underpinned by information from two sources: primary information and secondary information (Janssen, Chessa, & Murre, *in press*). Primary information is information stored at the time of encoding, about who the participants were, where and when it occurred, and what happened (following Wagenaar, 1986). This can include memory for the time of day, weekday, or day of month. Alongside this is secondary information, containing information about the context of the event, such as where one was working, and any nearby landmark events.

A fruitful approach to investigating the relative involvement of these types of information is to use public events, rather than autobiographical events. Public events, like autobiographical events, occur at a distinct, remote point in time, and if sufficiently memorable, attain permanence in the memory systems of those who experienced them. Memory for public events must therefore be supported by similar structures to those that support autobiographical memory. Experience of public events is shared by populations, rather than merely those who were directly involved, and thus offers the makings of a standardised tool to be applied across research participants.

Public events also make it easier to preserve a distinction between event-based information, and information from personal context. Autobiographical memories in the narrow sense, meaning personal well-remembered events, make it harder to fractionate distinctions between information that

derives from the memory itself, and information from associations between the event and a wider context. In considering a day-trip from my past, remembering who accompanied me is an instance of internal information, but if that person has a specific status within my autobiographical history (ex-girlfriend, room-mate at university) it could also be considered as contextual information. The fall of Saddam's statue, meanwhile, could yield information that is event-specific (recalling a number of jubilant Iraqis surrounding the shattered monument) that is totally disconnected from my personal history, or I might remember that it occurred just after my birthday, or while waiting upon the results of a job interview. Such events offer a more straightforward way of assessing the contribution of external or secondary information. Public events have been used in a number of studies investigating time for remote events (N. R. Brown, 1990; N. R. Brown et al., 1985; Burt & Kemp, 1991; Crawley & Pring, 2000; Ferguson & Martin, 1983; Friedman & Huttenlocher, 1997; Janssen et al., in press; Kemp, 1988, 1994; Wright & O'Muircheartaigh, 1997), and their use is appropriate here.

This chapter considers dating of public events, such as the fall of the Berlin Wall. It compares differences in strategy between young and old participants, and attempts to tease apart different contributions of event-based and autobiographical knowledge. One possibility is that time itself is directly encoded into the memory for an event. This view argues that along with encoding contextual information related to an event, there is an additional internally-generated code that is encoded that specifies the time of the event (G. D. A. Brown & Chater, 2001; Hasher & Zacks, 1979). This code may bear no relational to conventional time-based codes (seconds, hours, days, etc.) but may relate to 'neural oscillators' that operate over different time scales. The evidence in favour of such a theory has typically come from studies involving short-term retention of unrelated items in a list (e.g., G. D. A. Brown et al., 2000; this is discussed more fully in Section 1.2). Experiment 7 focuses on this possibility by comparing patterns of performance of two populations for events only experienced by one population. Another possibility is that temporal information is reconstructed almost entirely at retrieval through the use of contextual cues and inference (Friedman, 2001). Experiment 8 investigates the contribution of one such contextual cue, derived from the personal life history of the participants, relative to a number of internal memory measures.

Experiment 7 — Effect of episodic experience on dating accuracy of events

This study aims to tease apart some of the competing mechanisms discussed above in a task involving public events (akin to the method used by O'Connor et al., 2000). It specifically examines

the role of internal memory information, in two forms. The first of these is the role of degree of information about the event itself - what happened, who was involved, and so on. This is a kind of primary information (Janssen et al., in press). Research is equivocal on the relationship between level of event information and event dating accuracy; Burt (1992) suggested that degree of event knowledge did not affect dating error, whereas others (Kemp, 1988; Thomson, 1988; Wright & O'Muircheartaigh, 1997) show that a higher level of knowledge about an event leads to more accuracy in dating. This study hopes to contribute to this literature.

The second form of internal memory information is that conferred merely by experiencing an event. Accounts of memory that posit a time-code or some form of temporal organisation (G. D. A. Brown & Chater, 2001) claim any event that is experienced is laid down into memory with a code or stamp possessing useful temporal information. This implies that events that have been experienced should, other things being equal, be better dated than events that are not. One would expect, specifically, that for events equally well-remembered by a set of participants, those who had also experienced it should show better dating performance. Against this, reconstruction approaches do not presuppose that experience of an event necessarily leads to better dating for that event; changes in dating accuracy would be mediated by the extent to which the stored information offers useful cues as an aid to inference and reconstruction, rather than irrelevancies or misleading information.

This experiment compares the performance of two groups of participants, one composed of young and another of older adults. The young participants were unborn (or in childhood) for most of the events used and, thus, are unable to use autobiographical or other pertinent temporal information (e.g. distance-based) to estimate the dates. Their performance will be measured using the Public Events Knowledge Task (PEKT) created for this research. This method effectively allows an investigation of the dating of historical and lived events, *for the same set of events*.

Method

Participants

The participants consisted of 24 young (aged 19–24, mean = 20.1 years) and 16 elderly (aged 67–81, mean = 73.7 years) people. Elderly participants were recruited from a participant database at University College London who had previously responded to an advertisement in the local media. Elderly subjects were tested with these tasks alongside a larger battery that will not be described here. Young subjects were recruited specifically to perform the tasks described.

Background assessment

All subjects completed the same set of tests, with age group serving as the variable under investigation. The test battery was composed of a number of standard psychometric tasks: two measures of intelligence, the NART (Nelson, 1985) and Ravens Progressive Matrices (Court & Raven, 1986); three measures of executive function, Verbal Fluency (Benton & Hamsher, 1976), Cognitive Estimates (Shallice & Evans, 1978), and Trail-making (Reitan, 1971); and a two-part measure of memory, Logical Memory - Immediate and Delayed (Wechsler, 1984). This allows comparison of measures of cognitive traits that might differ between groups drawn from different populations, such as memory and IQ, in order to assess whether these traits contribute to any differences in performance.

Materials and Design

Dating and knowledge of past events was assessed using a booklet containing multiple choice questions and answers - the Public Events Knowledge Task (PEKT). The PEKT booklet is composed of thirty sections, each regarding a single discrete event that was well reported at the time of occurrence. Events were chosen from the *Chronicle of the 20th Century* (Legrand, 1988), with more recent events from the nineties selected according to their prominence on 20th Century history websites. Ten events from 1970–1980, ten events from 1981–1989 and ten from 1990–1998 were included. Each section began with a one-sentence description of the event, containing enough information to refer specifically to the single event: “Football fans crushed to death in ‘Hillsborough’ disaster.” Following this were two questions probing knowledge of the event, in this example asking the allegiance of the supporters who died, and the casualty toll. In each case answers were choices between four candidates. The section was completed by a further multiple-choice question, this time on the date of the event. The lure items (incorrect dates) were distributed at 9-year intervals away from the true date, with the position of the true date in the time-continuum being counterbalanced between all possible ones. The thirty sections were arranged in a random (i.e., non-chronological) order. A sample page from the PEKT is shown in Appendix C, and the list of events and question in Appendix D.

Procedure

The tasks were performed within a single session. Psychometric tasks were conducted according to standard procedure (e.g., Hodges, 1999). These tasks each took between three and ten minutes to be completed. The order of the tasks was not critical to the study, but one task (Logical Memory) comprised two components that had to be separated by a thirty-minute interval, which necessitated that the session should begin with that test. The PEKT was presented one section at a time, revealing each question after the previous was completed. It was completed by the participant by filling in the correct response for each question (A to D). In those cases where the participant had visual difficulties each item was read aloud while being visually presented and the responses were noted by the investigator. Every question required a response and participants were required to guess if they did not know the answer. For every participant a total score was then derived for each question (Content1, Content2, Dating), as well as an individual breakdown for each event.

Results

Tab. 4.1: Psychometric scores for young and older adult groups.

Trait	Test	Young adults	Older adult
<i>Executive Function</i>	Verbal Fluency	45.6	52.6
	Cognitive Estimates (errors)	5.29	3.87
	Trail making time (seconds)	90.6	141.3
<i>IQ</i>	RAVENS	9.96	8.73
	NART errors	18.2	5.2
<i>Memory</i>	Logical Memory I	27.4	30.4
	Logical Memory II	23.7	26.1

The results of the background psychometric assessment are shown in Table 4.1. T-tests conducted for each psychometric test revealed differences for two tests: the NART ($t = 6.337, p < .001$, where elderly performance was superior) and Trail-making ($t = 2.064, p < .001$, where elderly performance was inferior). Vocabulary knowledge is likely to be acquired accumulatively over time. This may give the elderly an advantage on this task. Trail-making is used as an index of executive impairment, but the motor component of the task may be responsible for this poor performance. Some of the participants exhibited visible slowing, and on the other executive tasks the performance of this group was better than that of the young. The samples did not show different performance on the remaining psychometric measures suggesting that they were generally well matched.

In the PEKT test, three questions were asked about each event, two regarding knowledge of details of the event (Content questions) and one about the date of the event (Dating question). Figure 4.1 displays these scores collapsing the data from the two content questions into a single measure. Figure 4.2 shows how dating accuracy is related to the amount of knowledge about the content of the event. This was achieved by considering separately those events in which participants were able to answer all the content questions correctly versus those events in which one or more content questions were answered incorrectly.

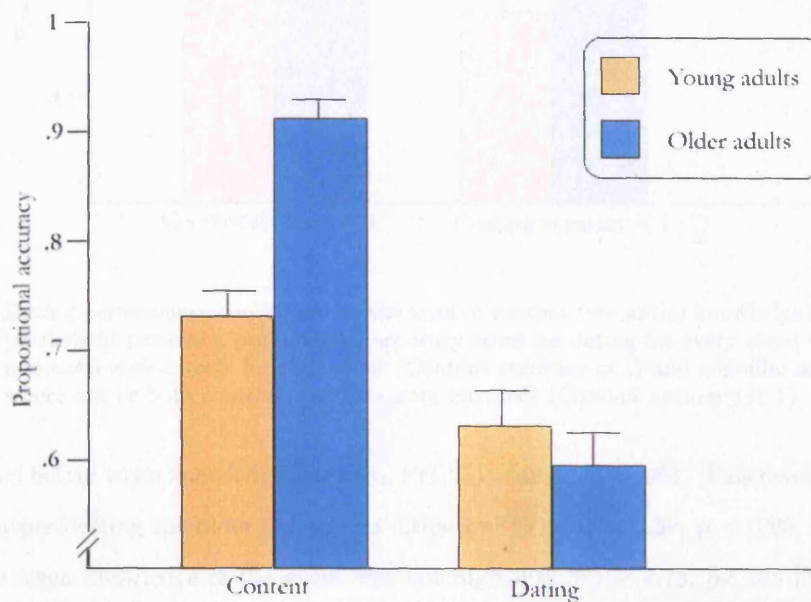


Fig. 4.1: Accuracy scores for content and dating over all thirty events.

Both groups were more accurate for content questions than for dating questions. Across all events, performance for dating was relatively similar across groups, but performance for content rather better for the older adults. For the young participants, performance was better for those events for which they had a high degree of content (semantic) knowledge. Meanwhile, the older adults do not appear to show this pattern.

The older group outperformed the younger group on the content questions, $t(38) = 6.362$, $p < .001$, but not for the dating question, $t(38) = .843$, ns. A 2X2 ANOVA (age group X degree of knowledge) on dating performance showed no overall main effect of age, $F(1,38) = .09$, ns, a significant main effect of the degree of knowledge, $F(1,38) = 9.31$, $p < .005$, and a significant interaction, $F(1,38) = 19.63$, $p < .001$. Simple effects revealed that performance in the older group remained steady across differing levels of knowledge ($F(1,15) = .45$, N.S.), whilst the younger group

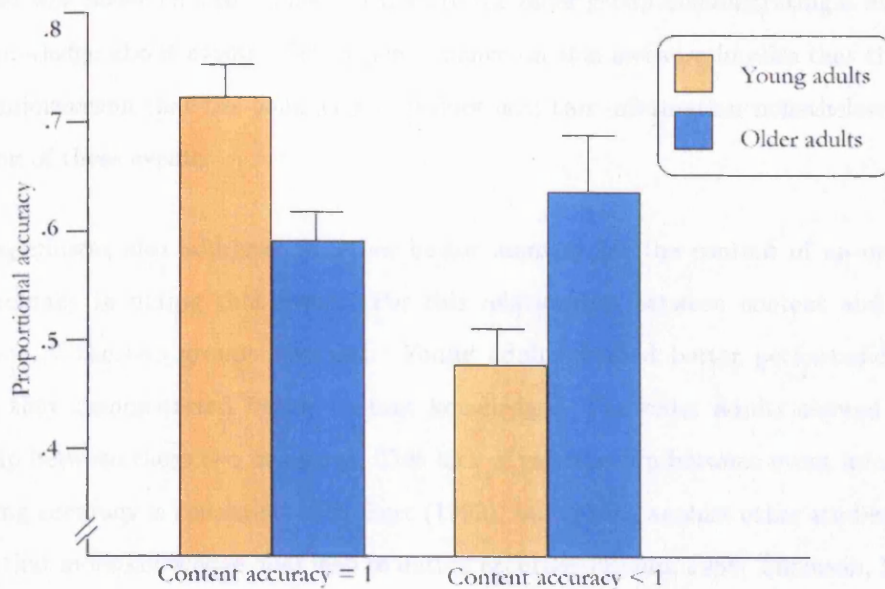


Fig. 4.2: Dating performance contingent on the level of content (semantic) knowledge of that event. Each participant receives a proportional accuracy score for dating for every event where both content questions were correct for that event (Content accuracy = 1) and a similar score for every event where one or both content questions were incorrect (Content accuracy < 1)

performed better when knowledge was high, $F(1,23) = 49.74$, $p < .001$. This resulted in the younger group outperforming the older one in this situation, $F(1,38) = 9.39$, $p < .005$, whilst the reverse was true when knowledge of the event was not high, $F(1,38) = 4.74$, $p < .05$ [NB - Levene's test revealed unequal variance for this measure between groups so the F was corrected accordingly].

For younger adults, events that they know more about are dated more accurately, whereas the dating performance of the elderly does not depend on their level of content knowledge. For these individuals, events that they know more about are not better placed in time (with a trend in the opposite direction).

Discussion

This experiment was concerned with the contribution of internal information from a memory to judgments on their time of occurrence. It specifically examined the prediction that living through an event leads to better dating of that event. This prediction, derived from the implications of temporal organisation accounts of memory, was not supported by the data. Overall, older adults did not show better performance at the dating of events than young adults who were juvenile or

unborn during these events. Both groups showed a similar level of performance that was well below ceiling (and well above chance). This was despite the older group demonstrating a higher level of content knowledge about events. Better performance on this measure implies that the group has access to information that the younger group does not; this information nonetheless did not aid their dating of these events.

The experiment also addressed whether better memory for the content of an event leads to greater accuracy in dating that event. For this relationship between content and dating, the performance of the two groups diverged. Young adults showed better performance for events for which they demonstrated better content knowledge. The older adults showed a lack of a relationship between these two measures. This lack of relationship between event information and event dating accuracy is consistent with Burt (1992), but stands against other studies which have suggested that more knowledge does lead to dating accuracy (Kemp, 1988; Thomson, 1988; Wright & O'Muircheartaigh, 1997).

One outcome of this difference between groups is that focusing on dating performance on events for which participants recognised both content questions, younger adults in fact outperformed older adults. The reverse pattern was observed for events where participants made one or more content errors: older adults performed better than the younger group.

These findings are not consistent with theories that posit encoded memories to possess useful temporal information. Under these accounts, we would expect that when events are equally remembered, those that have been lived through (lived events) ought to outperform those that have not (historical events). Across all events, lived events did not outperform historical events; when comparing only events for which a certain threshold of content knowledge was reached, lived events were actually worse than historical events.

To summarise, the superior semantic knowledge about the PEKT events displayed by the older group did not translate into superior dating performance. Their dating of an event was not determined by their level of knowledge about it. By contrast, the dating accuracy of the younger group was influenced by level of semantic knowledge, causing them to score higher than the older group when their overall knowledge was high. The present study does not offer an adequate explanation of why the older group under perform on dating accuracy relative to what is expected given their knowledge of the event, and the fact that they lived through them. It is possible that this reflects a more general difficulty in placing memories in time (Parkin & Walter, 1992). These

authors suggest that older adults may show a specific deficit in ordering memories due to frontal dysfunction. It should be noted that our older sample scored better on two measures of executive function than the younger group, and performed worse on a measure increasingly considered a psychomotor task due to its demand for speeded performance, and as such do not present a frontal profile. However, this study cannot exclude this possibility. It should be noted that this account in itself does not explain why the older sample does not show the relationship between content and dating seen in the younger sample, which implies more than simply poorer performance. It is also possible that the elderly are using a different source of information relative to the young adults. Experiment 8 attempts to investigate this directly by getting them to place events on a timeline of lifetime periods from their own life. I also examine two other measures that tap forms of internal information other than primary memory, in order to assess their contribution.

Experiment 8 — Factors that account for adults' dating of experienced events

Experiment 7 found that the level of factual knowledge about an event does not appear to moderate dating accuracy for individuals who have lived through this event. This experiment explores other factors that may influence dating of the event. It will consider the role of internal information from the memory itself: memory qualities and information about the event, and external information from the event's relationship to a surrounding context.

Information about the memory itself can come in two forms. The first is primary information (Janssen et al., in press; Wagenaar, 1986) about information within the event, such as who was involved and where it occurred. In Experiment 7 this type of information did not distinguish accurately and falsely dated information in the older adult group. This experiment offers an opportunity to replicate this pattern of results. Additionally, information may not come from aspects within the memory, but from qualities of the memory. Janssen et al. (in press) suggest that when direct information is not available, familiarity is used to determine when events have occurred, and Friedman and Huttenlocher (1997) demonstrate that distance-type processes that would depend upon some form of unitary information such as trace strength are involved in dating judgments under certain conditions. There is some evidence that qualities of events do distinguish accurate and falsely dated events. Consequently, this experiment employs two candidate measures to be investigated using the set of items within the PEKT.

The first of these is based on the impact the event had at the time, which I will term *strikingness*.

Investigations of flashbulb memories suggest that events which have a substantial impact at the time they occur are likely to be better remembered. When events are perceived to have high consequentiality, cognitive effort (but, contra R. Brown & Kulik, 1977, possibly not a distinct neural mechanism) is spent to anchor information about the event. Conway et al. (1994) investigated memory for the resignation of then prime minister Margaret Thatcher; the results suggested that greater accuracy in remembering the event was tied to its perceived consequential importance. The experiment will probe participants for their ratings of how striking each event was at the time it occurred.

The second of these is based upon the subsequent *memorability* of the event. This is concerned with how the event now appears to the individual - if they have a vivid sense of the event, and its use as a cue elicits a recollective experience. White (1989; 2002) used the researcher's most willing test subject — himself — in order to investigate memory for remote autobiographical events. Over each recall period (at delays of 1,2,6, and 20 years) vividness showed a steady and significant correlation with probability of recall. The experiment will probe participants for their ratings of how memorable each event was at the time of testing.

One measure that was also considered was emotional intensity. However, White (2002) revealed a high correlation between this measure and vividness, and the relationship between emotional intensity and recall was negligible once vividness was partialled out (not the case for vividness and recall). Consequently, the three internal measures used were event knowledge (once again), strikingness, and memorability. Use of these measures is particularly important in light of the argument made by Bastin, Van der Linden, Michel, and Friedman (2004) that aging is associated with a shift from reconstructive processes to distance-based processes. If this is the case, then our participants may be employing more distance-based processes which explain their decreased reliance on semantic information.

Alternatively, dating of events may depend more upon the reconstructive processes emphasised by Friedman (1993; 2001). The term reconstructive is used to capture the fact that the time of the event is inferred from other types of retrieved contextual information and is not an intrinsic property of the memory for that event. Autobiographical memories may be a particularly important source of constraint on placing events in time. In the influential model of Conway (Conway, 1992; Conway & Pleydell-Pearce, 2000; Conway & Rubin, 1993) autobiographical memory is hierarchically organised into three levels. At the highest level are 'lifetime periods' such as "working at X" and "living with Y". These periods are assumed to be ordered, although not necessarily dated. Thus, the model

contains some element of temporal organisation. Beneath this super-ordinate level lie “general events” such as “work vacation at W” and “drinks at Z on Friday evenings”. At the most subordinate level is the ‘phenomenological records’ of the details of specific episodes.

There is good evidence to suggest that autobiographical temporal landmarks (corresponding to lifetime periods and general events) are used to reconstruct the time of other events (e.g., Shum, 1998). For example, memories may be easier to recall when they correspond with temporal boundaries such as the start/end of term (Robinson, 1986). Dating can be more accurate if cued to a specific event “did you do X after Mount St Helens erupted?” relative to cueing to a time period “did you do X in the last 6 months?” (Loftus & Marburger, 1983; Prohaska, Brown, & Belli, 1998). Finally, the day of the week of an event is often remembered better than the month or year, suggesting that the time of events is reconstructed using information about ones weekly routine (Friedman & Wilkins, 1985).

There is widespread agreement that lifetime periods (or something much like them) are psychologically real entities. It also seems intuitively clear that locating events within these periods should assist in their dating, as the periods ought to be demarcated by boundaries whose temporal location is well-rehearsed and hence available. Research confirms that these participants do invoke autobiographical periods when attempting to date public events (N. R. Brown, 1990). However, no quantitative measure has been devised to measure how an event may be situated in terms of lifetime periods. In this experiment I shall attempt to do so using a modified version of the tool used in Experiment 7. It follows the format used by Conway and Bekerian (1987) of eliciting periods from subjects themselves. It differs in enforcing non-overlap between life periods and attempts to ensure that the time span over which public events occurred was not uniformly dominated by a single lifetime period, and yields from this a quantitative measure of ‘personal specificity’, in terms of the duration of the window within which events are judged to have taken place.

This measure allows us to assess if patterns of performance are consistent with the use of reconstructive methods that employ temporal information from the lifetime period. If such information is used, it will be of most benefit from the lifetime period individuals can place the event within is narrow: in this case, the event must have fallen on one of a small number of years. The information will be of less use when the lifetime period an individual places the event in is a wide one, or individuals are uncertain about which of two candidate periods the event fell in: in these cases, the event may have fallen on one of a wide number of years, and hence dating is less likely to be guided to the correct response.

Method

Participants

Sixteen older participants (range = 57–78 years, mean = 67.1) were recruited from the same sources as the previous experiment. None of them had been involved in Experiment 7. A younger group was not required given that the our hypothesis relates to placing events in autobiographical context, or making judgments about phenomenal aspects of the memory, and younger people did not live through most events.

Timeline construction

Before administration of the Modified PEKT, subjects were required to construct a timeline depicting distinctive periods within their life. This was achieved by dividing a line drawn on A4 paper into sections by bisecting it with pen strokes. In each case, the investigator first presented an example by partitioning a sample line into school and further education; then showing how it could be further subdivided on the basis of different addresses; finally producing a line partitioned into the following periods: KENTON SCHOOL — STANMORE SCHOOL — SECONDARY SCHOOL — UNIVERSITY — PLYMOUTH — GLASGOW — GRADUATE STUDIES. It was made clear that the intent was to produce a coherent description of their life as a sequence of discrete periods, using whatever criteria was appropriate to the participant, whether occupational, residential or personal.

Once the subject had produced their hand-produced timeline it was translated by the investigator into a spreadsheet version, placing events into successive cells on a single line. This was an interactive process allowing for clarification and streamlining of information, such as merging some periods into a single cell description. For example, if the participant worked four or five casual jobs in the 18 months after leaving school, before embarking on a career, then this period might be labelled “Various jobs after school” and placed in a single cell. When a provisional timeline is completed, the subject first corroborates whether this is a fair description or whether it distorts aspects (e.g. the timeline may have been labelled with ‘Wales’, but seeing it as a discrete cell leads to the clarification that this does not denote a single period but the beginning of an overlapping period in which Wales was regularly visited).

During piloting, some participants volunteered periods that were very wide, up to twenty or thirty years that largely overlapped with the entirety of the period addressed within the Modified

PEKT. To avoid this, participants were asked at the end whether any period was substantially longer than the others, such as fifteen or more years. If such a period was identified, the subject was asked if there was a meaningful criteria by which the period could be divided into multiple periods, such as a change in job description in a lengthy period working for an employer, or a new job or hobby whilst a lengthy period at an address. If (and only if) the subject could freely volunteer such a division that made sense to them, the timeline was amended to include this. Once the timeline had been finalised it was copied and pasted to form a stack of thirty identical timelines on separate rows, one for each of the public events used in the experiment.

Materials and Design

This experiment used a modified version of the booklet described in Experiment 1. The events and questions were exactly the same as the previous version. However, a number of additional questions were asked about each event in order to determine the strategy used to place them in time. Specifically, they were asked two questions about qualities of their memory for the event, and a prompt for the use of the timeline earmarked for that event. The questions were “How striking was the event at the time?” and “How memorable is the event now?” Each question was set above a rating scale of the numerical responses and an accompanying description comprising 1 (not at all), 2 (a little), 3 (somewhat), 4 (highly), and 5 (incredibly). These features were inserted after the knowledge questions but before the dating question.

Procedure

First of all, participants produced a timeline as described above. Following this participants were briefed as to the nature of the task, explaining the format of questions, the scales to be used to rate the qualities of the event, and how the timeline would be employed within the task. The PEKT was presented section by section, revealing each question after the previous was completed. For simplicity the investigator recorded all responses. These were firstly the responses to the two content questions, in the manner of Experiment 7.

Following this, participants gave numerical ratings of strikingness and memorability using the 1–5 scale described above. The next response involved the constructed timelines: subjects were instructed to inspect the timeline, with respect to the event in question, and decide within which

period or periods they were confident the event had occurred within. It was made clear to them that the number of periods they selected was entirely up to them, and that they should feel no pressure to select a single period when they thought it possible it could also have occurred within a different period. It was also made clear to them that the timeline was there as a tool rather than a prescription, and that should an event elicit an autobiographical period that was not described on the timeline (or only described in a general sense) then they were free to specify this, for example “the summer of my last year at 2ndary school where I was bed bound due to tonsillitis”.

Participants were told to try to perform this task by thinking about which period(s) were congruent and consistent with the occurrence of the date, for example “I never voted in that election — it was the year I was in China”. They were explicitly discouraged from allocating an event to a period on the basis of its estimated date, for example “Thatcher is three Prime Ministers ago so must be twenty years since she came in, so I suppose it must have been the year I spent in China”. A computer screen displayed the copy of the timeline earmarked for that event, in Excel format, and the investigator deleted those cells the subject was confident the event did not occur within. The screen was then scrolled to a fresh timeline. Finally, participants were asked to select a date from the multiple-choice options.

After the task was completed, participants provided durations for each cell in their complete timeline. This allowed a personal specificity score to be computed for each event, based on the sum of the durations for the cells selected for that event.

Results

This experiment provided an opportunity to replicate the findings of Experiment 7 with a different sample. Indeed, this second elderly sample performed identically to the previous elderly group, both in terms of accuracy of content information retrieved, $t(30) = .221$, ns, and for dating accuracy, $t(30) = .540$, ns. The main purpose of this experiment was to determine what type of information this older group rely on to date memories, if not content (semantic) knowledge of the event itself.

To investigate the type of information used to support dating judgments participants were asked to rate the ‘strikingness’ of the event at the time, the ‘memorability’ of the event now and also to place the memory on an autobiographical timeline. To analyse these influences, events were back-sorted into bins based on subsequent dating performance for each participant. The

average performance on the other measures was derived for each bin, producing a score for Content—Dating is True (i.e. amount of content knowledge given that the event was dated correctly) and a score for Content—Dating is False (amount of content knowledge given that the event was dated incorrectly), and likewise for Strikingness and Memorability. The results are summarised in Figure 4.3. Accuracy was similar for correctly and false dated events: for Content 1.84(.13) versus 1.83(.18) for Strikingness, 3.55(.52) versus 3.51(.61), and for Memorability, 2.6(.71) versus 2.5(.80). These differences proved to be non-significant in each case: Content, $t(15) = .353$, Strikingness, $t(15) = .458$, Memorability, $t(15) = .982$.

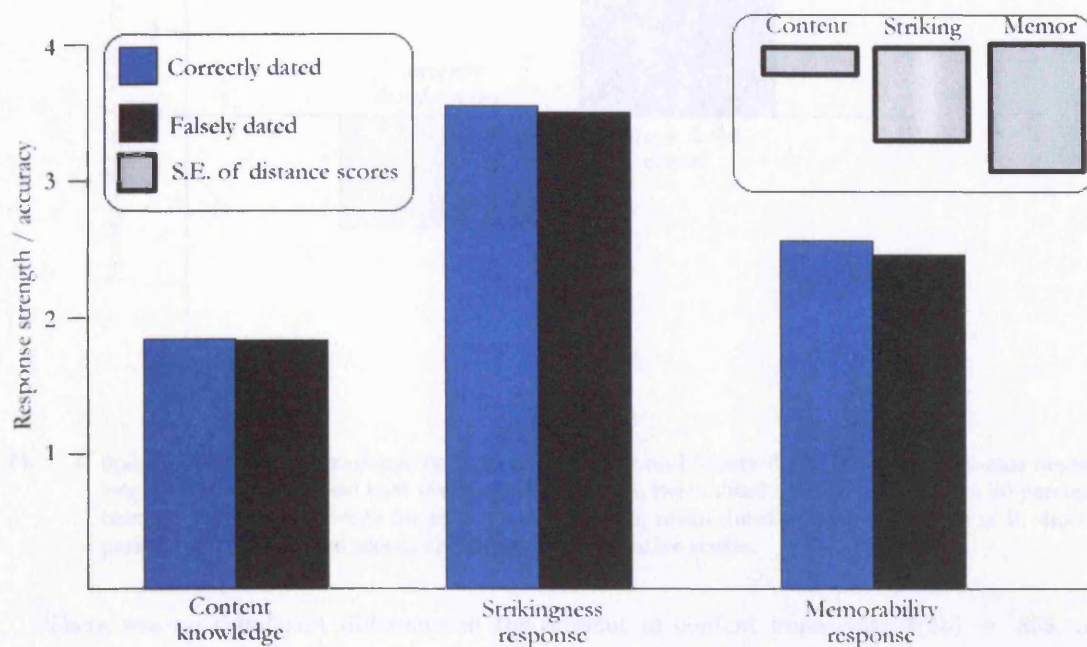


Fig. 4.3: Knowledge scores and memory ratings for correctly and incorrectly dated events.

Turning next to the influence of autobiographical knowledge in event dating, it was necessary to find a way of scoring their use of periods on the timeline. For each event, participants indicated which period or periods of their life they thought the event had occurred in. It was then possible for the experimenter to score this in terms of the length of the time window in which the participant felt the event occurred (e.g., within a 3 or 10 year window). Given that the length of the windows varied between participants (as well as between events), these were standardized to z-scores for each person, whereby a score above zero was given when a given window had a greater length than their mean response, and a score below zero when the window was lower than their mean. Thus, each event could be quantified according to whether it is placed within a narrower or broader time window in relation to their particular timeline. Figure 4.4 shows that events dated accurately are placed within a narrower autobiographical time window relative to incorrectly dated events.

This effect was statistically significant, $t(15) = 3.742$, $p = .002^1$. It is interesting to note that autobiographical context had no influence on the accuracy of performance on the content knowledge questions, $t(14) = .556$, ns².

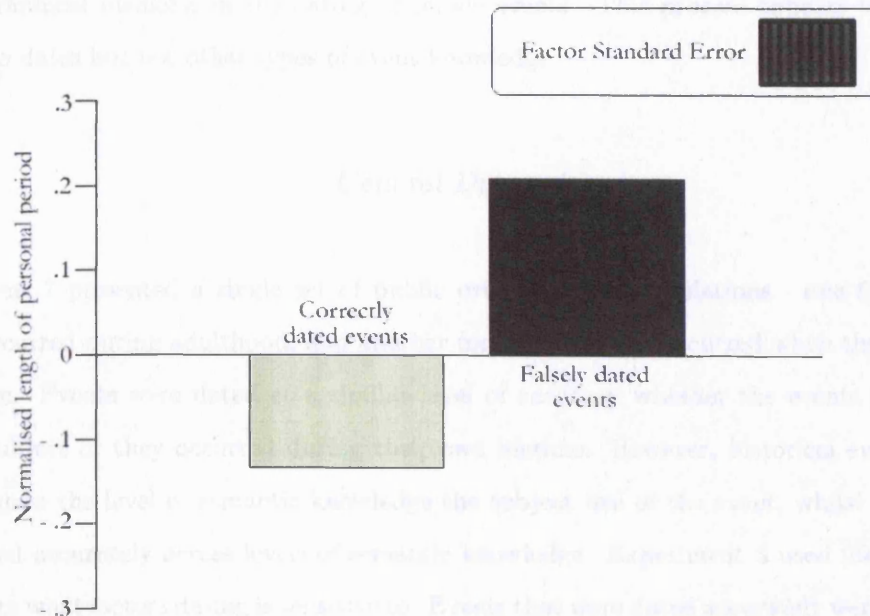


Fig. 4.4: Specificity of autobiographical context for correctly and falsely dated events. The y-axis depicts length of personal period that events were placed in, normalised such that across the 30 personal contexts assigned to events for each participant, the mean duration yielded a score of 0, shorter periods yielded positive scores and longer ones negative scores.

There was no significant difference in the amount of content knowledge, $t(15) = .353$, ns, strikingness, $t(15) = .458$, ns, or memorability, $t(15) = .982$, ns, between events dated correctly versus events dated incorrectly. Thus, none of these factors provide a satisfactory account of how memories are placed in time — at least, for people who lived through such events.

Discussion

In summary, Experiment 8 has replicated and extended the findings from Experiment 7. It shows that overall accuracy at dating events is not affected by the amount of knowledge of the event. The experiment also rules out the suggestion that dating is based on how striking the event was at the time, or how memorable it feels now. This would have been predicted if they were dating

¹ The pattern of results reported was identical when the raw data was used.

² This analysis followed the categorization applied in Experiment 7 into events with no errors in content knowledge, and those with one or more errors; one subject was excluded as their knowledge was flawless across events, preventing any comparison.

events using distance-based measures. Dating accuracy is predicted by the participants' ability to place the event within a more narrow window in their autobiographical time line.

These results underscore the importance of reconstructive processes, particularly related to autobiographical memory, in the dating of public events. This process appears to be relatively specific to dates but not other types of event knowledge.

General Discussion

Experiment 7 presented a single set of public events to two populations - one for whom these events occurred during adulthood, and another for whom events occurred when they were a child or unborn. Events were dated at a similar level of accuracy whether the events were historical for the subject or they occurred during their own lifetime. However, historical events appear to depend upon the level of semantic knowledge the subject has of the event, whilst lifetime events were dated accurately across levels of semantic knowledge. Experiment 8 used lifetime events to investigate what factors dating is sensitive to. Events that were dated accurately were found to have a more specific personal context period assigned to them, but did not differ in rated strikingness or memorability, nor (again) the level of semantic knowledge.

The data offers no support for the supposition that long-term remote memories contain intrinsic codes that offer useful information to the dating process in an additive manner. When events were experienced directly rather than historically, event content was superior but this did not translate into better dating; in fact, when content information was matched the older group (who experienced events directly) actually performed rather worse. This suggests that in some situations experiencing an event may offer no special advantage to its subsequent dating. This lends credence to reconstructive accounts, for whom experience is only predicted to be useful to the extent that it offers cues and information for inferring the location of an event. It conflicts with accounts of memory that posit a scale-invariant organisational principle of memory along chronological lines (G. D. A. Brown & Chater, 2001). It should be noted that this does not preclude the possibility that autobiographical memories are internally organised in some chronological manner (see e.g., S. J. Anderson & Conway, 1997); components of an event may be affixed to a narrative frame or schema such that recall of the event involves running through it sequentially.

Previous research has produced contradictory findings concerning the relationship between level of event information and event dating accuracy. Burt (1992) suggested that degree of event

knowledge did not affect dating, whilst others (Kemp, 1988; Wright & O'Muircheartaigh, 1997) show that a higher level of knowledge about an event leads to more accuracy in dating. Our results suggest that level of event knowledge may only be important for dating events that are not easily integrated within autobiographical memory structures. The question of how individuals learn about (and represent) the temporal relationships between historical events that were not experienced is unanswered, but it may well differ from the way in which experienced events are represented (contrary to Kemp, 1994). It does appear that content knowledge (which, for historical events, amounts to semantic facts about the event) does distinguish correctly and falsely dated historical events.

It was also possible to test the hypothesis that events are dated using a continuous measure such as strikingness or memorability. However, these measures did not predict accuracy of dating. This does not rule out distance-based accounts in other circumstances. As Friedman and Huttenlocher (1997) suggest, this explanation may apply to more ephemeral events such as "60 minute" stories that are harder to integrate with schema-type structures containing other knowledge about the world or oneself. However, a number of studies have detailed some involvement of both distance-based and location-based information in event dating (Betz & Skowronski, 1997; Thompson et al., 1996). Finally, these results are incompatible with the suggestion that there is an intrinsic temporal code present in all memories that enables them, at retrieval, to be ordered in time (G. D. A. Brown & Chater, 2001). This theory would not predict the results of the autobiographical timeline, and would predict that episodic exposure to an event at the time it occurred (i.e., lifetime rather than historical events) should be more accurately placed in time through the use of its temporal code. Of course, these results do not disprove the claim that such codes exist but only suggest that they do not appear to be useful in this context. This is consistent with the wealth of other information concerning the role of reconstructive mechanisms in memory dating (e.g. Friedman, 2001).

These results underscore the importance of autobiographical context for placing events in time, including 'public' events. This is in line with the model of N. R. Brown (1990) wherein "there are contextual links that directly connect facts derived from news stories to facts about the personal context in which they were acquired or used." (pg 299), and with Tulving's (1983) characterisation of the "setting" of an episodic experience. It suggests that lifetime periods provide salient boundaries within which to place events pertaining both to ones self and to events around us in a similar way as do stand-alone temporal landmarks (Shum, 1998). This is consistent with results from studies by N. R. Brown et al. (1985) and N. R. Brown (1990) employing talk-aloud protocols to study public event dating, in which autobiographical information was commonly volunteered:

contextual information was in fact the most common response type in the N.R. Brown study. The current study may be seen as a quantitative confirmation of the role of autobiographical information that these talk-aloud studies have revealed. It is also consistent with the finding of Conway and Bekerian (1987) that personal periods act as an effective prime for other events from that period. These results are also in line with an associative theory of dating put forward by Kemp (1999). Kemp used simulations of dating errors to argue it is the contextual information that underlies a period of time that is the basis for making dating judgments. This model assumes that information comes from a number of sources — autobiographical, public and everyday; limiting ourselves to autobiographical information, I have demonstrated using a quantitative technique that contextual information does affect accuracy of dating.

Janssen et al. (in press) detail a model in which events are dated using either a location-based method (either recalling primary temporal information such as the date, or inferring using secondary temporal information, such as proximity to landmarks) or a distance-based method based on familiarity, depending on whether the event is recent enough to support the former, more accurate process. Janssen et al.'s model assumes that when accurate judgment is not available at one level (e.g., primary information) the system steps to the next one, which would suggest that participants should show better performance when more information is available. In Experiment 7, participants without experience of events dated them as well as those who have had that experience, despite lacking access to the kinds of secondary temporal information available to the latter, nor the same sources of familiarity-based information. This suggests that these information sources (primary, secondary, familiarity) may not be additive and complementary but may present different routes that participants may adopt, and are not always readily accessible by other sources of information.

Given that the data shows that the specificity of autobiographical context is related to accuracy in dating, one might have expected that the participants in Experiment 8 would outperform their equivalents in Experiment 7 who were not prompted with this strategy. However, this was not the case. It may be that the strategy imposed on them in Experiment 8 is similar to the one that is used spontaneously (in Experiment 7), which is also suggested from the experiments employing talk-aloud protocols described above. It should also be noted that for this sample the set of events used tended to fall beyond the period of years associated with the reminiscence bump (e.g., Jansari & Parkin, 1996; Janssen, Chessa, & Murre, 2005). The reminiscence bump refers to the increased tendency for older adults to recall events from their early adulthood. It may be related to the fact that this period is associated with significant life changes (first job, first partner, etc.). These

may serve as salient temporal landmarks (Shum, 1998), and it would be interesting to see whether public events that fall within this period show less or more sensitivity to lifetime periods when a number of stand-alone temporal landmarks are available, or whether it is fruitful to consider the early adulthood span as a series of distinctive lifetime periods bounded by these significant “first experience” memories (Robinson, 1992). It would also be interesting to investigate elderly dating performance for sets of historical and lived-through events. Should the historical events show the same relationship between content and dating seen in the younger group in Experiment 7, with the lived-through events showing this independence, this would add support to the idea of distinct routes rather than additive sources of information, and would do so within a single group, avoiding the issues of potential confounds brought in by different age groups. Of further use would be a replication using lived-through events with adults too young to be contributing ageing-based confound to the findings.

In summary, I have demonstrated that dating accuracy for events that have not been lived through is related to their level of knowledge of the event, contrasting with older subjects whose performance is neither related to degree of knowledge, nor measures of current memorability or strikingness at encoding, but is instead related to the specificity to which the event can be tied to their personal history in terms of life periods. This questions the degree to which dedicated temporal information intrinsic to individual episodic memories may be aiding dating of an event, instead offering further evidence for the temporal organisation of autobiographical memory being achieved through the lending of temporal information from one hierarchy (life periods containing clear temporal reference points) to another (specific events which can be localised within these periods).

5. NEUROPSYCHOLOGICAL INVESTIGATIONS INTO TEMPORAL MEMORY

Neuropsychological studies allow the investigation of faulty cognitive systems in order to make inferences as to how the healthy system achieves its functions. This chapter will ask a question that resonates with the theme of this thesis: is temporal context memory the product of a dedicated timing system or of features of general memory function? To do so, it will address two issues. The first is the extent to which temporal context memory is dissociable from other forms of context memory. The second is the extent to which temporal context memory is dissociable from time duration estimation.

This chapter details the performance of a case series of neurological patients in a number of investigations. Experiment 9 details the relationship between various forms of context memory: memory for spatial position, associative recognition for items presented simultaneously, and two measures of recency memory, within- and between-list recency. At issue is the degree to which these abilities depend upon the same memory processes and neural substrate. Experiment 10 investigates whether the ability to make accurate interval timing estimates is related to accuracy in temporal memory judgments, as one would expect if the two are both subserved by oscillator systems that mark the passage of time.

Experiment 9: Deficits in context memory

In a number of neuropsychological studies a useful distinction has been made between memory for item and memory for source (Johnson et al., 1993). Brain damage may make it difficult to retrieve past instances or learn new information; alternatively, items may be recognised or recalled, but without information that distinguishes its origin, or source. Source is used to mean a number of things, including modality (Ward & Parkin, 2000), reality versus imagination (Johnson, 1988) and

at times temporal context is conflated as a form of source, or task demands shade the distinction between the two, such as when discrimination between temporally separated lists is employed,

One useful function this distinction has served is in helping to characterise the memory function of patients with damage to the frontal lobes. In a review of the effect of frontal lobe damage, Stuss and Benson (1987) state “innumerable studies on patients with many different types of frontal lobe disorders have failed to reveal any deficits on basic memory tests” (pg 149)¹. Careful work drew attention to ways in which memory could be strikingly affected in these patients, one prevalent feature being that of impaired recall relative to recognition memory (Parkin, Leng, Stanhope, & Smith, 1988; Volpe & Hirst, 1983); another was the failure of some patients across a number of these tasks labelled as source memory. However, as I shall describe below, it is unclear whether frontal patients are poor for all these types of memory, and whether source memory deficits are particular to frontal damage. For the purposes of this thesis, these are pertinent issues, which speak to the question of whether temporal context relies on dedicated mechanisms or is the consequence of the operation of broader memory processes.

Is temporal context merely a special instance of source memory? Is asking when an event occurred the same kind of question as asking where an event occurred, or whether an event was heard or read? Work in different sub-fields typically argues that each ability is distinct, and underpinned by different information. For example, temporal context may be inferred through the use of dedicated information appended as a time tag. This would be distinct from its spatial context, which might be inferred through the operation of a system dedicated to registering location within a spatial environment (N. Burgess, Becker, King, & O’Keefe, 2001), an idea that has gained support through single-cell recording evidence (O’Keefe, 1991). Separate from both would be reality monitoring, a type of context inferred through the successful operation of monitoring-appraisal systems which form part of the apparatus of the mnemonic system (Johnson & Raye, 1981).

Theories that propose specific and distinctive mechanisms for recovering spatial, temporal and other contextual informations are in contrast to those which suggest there is only one problem: the recovery of source information about a memory. In an early paper on source memory, Schacter, Harbluk, and McLachlan (1984) argue “one of the central characteristics of the phenomenon is that in a situation in which memory for two attributes of an event is probed, subjects demonstrated

¹ NB This early view has now been superceded by demonstrations that more core memory features may be impaired by frontal lobe damage (Wheeler, Stuss, & Tulving, 1995)

knowledge of one attribute but not the other" (pg 594), and draw parallels between situations in which the colour of an object is recalled but not its location (G. V. Jones, 1976), and those in which the verb clause of a sentence is recalled but not its object (J. R. Anderson & Bower, 1971). Under this view there may be a single general process: the ability to trace associations from a retrieved item in order to enable a judgment about its experiential context. Under this view, temporal context could merely be another form of source. This view collapses onto contextual accounts of temporal memory, as it proposes that well-specified mnemonic information yields temporal context, by binding events to environments containing temporal landmarks, offering associations between events, and providing information sufficient to make causal inferences between them.

Context for space and time

The neuropsychological literature is equivocal on the matter of the co-occurrence of space and time contextual memory deficits. Earlier work with frontal lobe patients, whilst emphasising source over item deficit, concentrated specifically on temporal context impairment, demonstrated in a number of studies (Kesner et al., 1994; Milner, Corsi, & Leonard, 1991; McAndrews & Milner, 1991; Milner, Petrides, & Smith, 1985; Shimamura et al., 1990); spatial memory, on the other hand, is reported as relatively preserved (Smith & Milner, 1984). This led authors to argue that "the prefrontal cortex is critically involved in the mediation of temporal information" (Kesner et al., 1994, pg 890) and that temporal organisation is "the most general function of the lateral prefrontal cortex". Spatial memory has been considered to be more impaired in cases of anterograde amnesia, with a number of experiments suggesting a failure to remember the spatial location of stimuli across a wide variety of tasks (Abrahams et al., 1999; Abrahams, Pickering, Polkey, & Morris, 1997; Holdstock, Shaw, & Aggleton, 1995; Milner, 1974; Milner, Johnsrude, & Crane, 1997; Smith & Milner, 1981; Warrington & Baddeley, 1974). Some studies report little or no impairment in temporal context memory with amnesic patients (Parkin et al., 1990 in temporal lobe amnesics; Squire, Nadel, & Slater, 1981 in patients with damage to dorsomedial thalamic nucleus), one notable exception being patients with Korsakoff's Syndrome, discussed below. It should be noted that many of these studies observe a spatial memory impairment when item memory is also impaired, and so suggests not a selective spatial context impairment but a concomitant one, and that there is much evidence to suggest that spatial context deficits are due to damage to the right hippocampus (Abrahams et al., 1999, 1997).

A clear case of dissociation between spatial and temporal context tasks can be seen in RK, a diencephalic patient reported by Parkin and Hunkin (1993). This patient performs poorly on tests of temporal memory but can perform spatial memory discriminations in a similar manner to controls.

In keeping with this pattern some researchers argue spatial memory is an intrinsic component of episodic memory. O'Keefe and Nadel (1978) argue that the episodic memory function of the hippocampus in humans emerges from its ancestral primary function of encoding spatial locations, as evidenced from work with rats. N. Burgess et al. (2001) propose a model of retrieval of spatial context that has as its rationale the idea that "the allocentric spatial representations of the hippocampus in rats have become co-opted to form part of the episodic memory system in humans by providing spatial context" (pg 255); other models (e.g. Recce & Harris, 1996) also make the assumption that the hippocampus is particularly crucial in indexing spatial context.

However, cases have been reported in both the frontal lobe and amnesic literatures that run counter to this pattern of results. Firstly, the idea that deficits in temporal order memory are unique to frontal patients was challenged by a number of studies. Yasuno et al. (1999) report retrograde temporal order amnesia resulting from damage to the fornix; Bowers et al. (1988) describe a case where the lesion site was retrosplenial. Mayes and Daum (1997) report comparative temporal context deficits in their "posterior cortex" group as with their frontal group in a test of list discrimination. Kopelman et al. (1997) report a subgroup of herpes encephalitic patients showing a trend towards impairment for temporal context memory. Hopkins, Kesner, and Goldstein (1995) report hypoxic patients impaired at spatial location recognition, item recognition for abstract and non-abstract pictures and words, and order recognition across modalities and spatial location. Additionally, studies have been reported where frontal patients were not disproportionately impaired: Kopelman et al. report similar performance across temporal lobe and frontal groups of mild, non-significant impairment, whereas the frontal group of Mayes and Daum passed a test of temporal sequencing. In Kopelman (1989), temporal context memory was not significantly different between frontal groups classed as with or without frontal atrophy, and correlations between frontal and temporal context scores were low and only a few were significant; moreover those few significant correlations are lost after partialling out the influence of memory quotient, which itself showed a stronger relationship with temporal context.

The equivocal nature of these findings leaves the status of temporal context memory in amnesics unestablished. Some of these conflicting data may be the consequence of the tasks used. Hopkins

et al. (1995) used a slightly unusual approach to assessing item memory, in that each target and items from the pool of foils was presented and re-presented across different trials, requiring in some instances a source judgment (whether the item had been seen in the study phase or on a previous test trial) rather than a true recognition judgment. A similar method was involved with the order task, meaning that recency judgments were demanded on items that had been subsequently seen 'out of order' which may have affected the task. Parkin et al. (1990) rather more deliberately used a type of stepwise recognition paradigm, with participants being required to select those items they saw only in the previous set, rejecting previously presented foils. Such a task could reflect the ability to update and maintain what information is currently relevant, and in fact researchers using a similar task do argue it taps this ability, rather than temporal context per se (Schnider et al., 2000). Squire et al. (1981) uses a between-list discrimination task to measure performance of a single patient against a small ($n=4$) control group. Kopelman et al. (1997) also uses between-list discrimination, but with a much larger sample size (14 temporal lobe versus 20 controls as well as other patient groups). This study uses a titration procedure to present its study items in order to match recognition across groups, which some authors have suggested may create an artifactual impression of the relationship between recognition and other measures which depend more upon recollection and context than familiarity (Giovanello & Verfaellie, 2001). On the other hand, titration does avoid the scaling problems that can result when investigating relative impairments in groups who differ in level of performance on both measures. Despite this, there may be some benefit of examining this issue without recourse to a titration procedure to establish whether convergent findings are obtained.

Secondly, the sparing of spatial memory deficits in frontal patients is not clear-cut. Frontal lesions impair route learning by human participants in maze tasks (Milner, 1965). Lesion data from monkeys show deficits in spatial working memory from frontal dorsolateral damage (Bachevalier & Mishkin, 1986). Moreover several neuropsychological studies show that frontal patients are impaired at spatial memory (Mayes & Daum, 1997; Owen, Downes, Sahakian, Polkey, & Robbins, 1990; Owen, Sahakian, Semple, Polkey, & Robbins, 1995). The Mayes and Daum study effectively shows the reverse effect of that commonly found, with patients with frontal lesions impaired at spatial but not temporal memory. Petrides (1982) reports frontal patients impaired at a test of spatial associative memory.

Thirdly, some studies have suggested a common basis for these types of memory. Treatments that reduce oxidative proteins in the brain, such as those caused by ischemic insult, result in better temporal and spatial memory in a radial arm maze test for older gerbils (Carney et al.,

1991). Across patient groups (focal frontal, temporal lobe, and diencephalic) Kopelman et al. (1997) demonstrated a correlation between spatial and temporal memory. It should be noted that in this study, a particular impairment for temporal context was found in a subgroup of the frontal patients, those with lesions that penetrated the dorsolateral frontal cortex. Interestingly, this is the same area implicated in spatial memory in animal lesion data.

Korsakoff's Syndrome must be considered separately from both cases of frontal lobe damage and temporal lobe amnesia, both for anatomical reasons and on the basis of their distinctive memory profile. Anatomically, Korsakoff's Syndrome involves the mamillary bodies and thalamus in the limbic system, along the midline of the diencephalon, and frequently additional damage to the frontal lobes, particularly the dorso-lateral region (Leng & Parkin, 1988). One account of the functional nature of the memory impairment in this syndrome is that it is due to "a selective defect of context memory" (Huppert & Piercy, 1976). Huppert and Piercy draw "a distinction between memory for an item of information (e.g. a picture, a word, or a unique event) and memory for the context in which that item of information occurred" — in that case, one of two temporally separated lists, which their Korsakoff patients failed to distinguish. Many studies have shown an impairment in distinguishing the temporal context of items (Kopelman et al., 1997; Parkin & Hunkin, 1993; Parkin et al., 1990; Shaw & Aggleton, 1995). Meudell et al. (1985) describe how the tendency for Korsakoff's patients to confuse recency and frequency is not purely down to poor memory; healthy participants under conditions that yield poor memory — such as a reduced exposure to items or a long retention interval — can show similar memory performance but are still able to make temporal context judgments independent of frequency. Korsakoff's patients also fail tests of spatial memory (Kopelman et al., 1997; Shoqeirat & Mayes, 1991). This has lead some (Parkin, 1984; Parkin & Leng, 1993) to argue that amnesia resulting from Korsakoff's Syndrome is qualitatively different from other amnesias. Some have argued that this is the consequence of concomitant frontal lobe damage "superimposed on a more basic memory disorder" (Squire, 1982, pg 560); however evidence from Parkin and Hunkin (1993) suggests that diencephalic damage in the absence of frontal pathology is sufficient to produce temporal context deficits. Against the case for a general contextual impairment are studies that report no impairment in spatial relative to item memory (Chalfonte, Verfaellie, Johnson, & Reiss, 1996; McAndrew & Jones, 1993), and the findings described above imply that they are not the only amnesics with a deficit in temporal context memory relative to target memory.

Correlational data also yields a mixed view as to whether frontal function is linked to temporal memory deficits. Studies with patients from a variety of aetiologies suggest that temporal mem-

ory is less strongly correlated with frontal lobe function than target memory (Kopelman, 1989; Parkin et al., 1990), spatial memory (Shoqeirat & Mayes, 1991), or modality-based source memory (Pickering, Mayes, & Fairbairn, 1989).

In summary, it is unclear whether frontal lobe damage produces a selective impairment in temporal context memory that is not accompanied by other (e.g., spatial) contextual impairments, or whether it is distinct from that observed in amnesic patients. Nor is it clear whether the contextual memory deficit observed in Korsakoff's Syndrome is generalised or applies especially to temporal context memory. It is also unclear whether non-Korsakoff amnesics show normal temporal memory or whether in some instances it is affected.

Is associative recognition different from other context judgments?

Another ability which may have some correspondence to these other forms of contextual memory is the ability to retrieve information about one items' correspondence to another, for example whether items were presented together, an ability termed associative recognition (Kelley & Wixted, 2001). Petrides (1982) describes impairments in frontal patients on both spatial and non-spatial association tasks; whereas Vriezen and Moscovitch (1990) described impairments in temporal memory and associative memory under certain learning conditions in Parkinson's patients. Meanwhile, a number of studies have reported impairments in associative memory within patients with temporal lobe damage (Kroll, Knight, Metcalf, Wolf, & Tulving, 1996; Mayes et al., 2004; Vargha-Khadem et al., 1997). These studies do not report performance on tests of temporal memory.

Mayes et al. (2004) argue that the hippocampus is required to make enduring associations between different types of information, such as picture-word associations. Such an ability underpins recollection on standard memory tests. They suggest that other mechanisms are involved in familiarity memory and in learning same-kind associative pairs, such as word-word associations. These mechanisms may reside in structures outside the hippocampus including perirhinal cortex and the cortex itself. This implies that associative memory for like items should in some instances dissociate from forms of source memory, which may rely on more recollective-like processes.

As described in Section 1.2.4, our ability to distinguish frequency and recency (Hintzman & Block, 1971) dictates that temporal context judgments are not made on the basis of familiarity alone. Consequently, on this account we might expect to see single dissociations where associative

recognition is preserved in the face of selective impairments in temporal memory. However, work in the experimental literature has suggested that manipulating maintenance duration (Nairne, 1983) or retention interval (Hockley, 1992) in associative recognition of word pairs leads to higher hit rates *and* false alarm rates in an associative recognition test, leaving d' effectively unchanged. A more recent formulation (Kelley & Wixted, 2001) suggests that item familiarity makes a partial contribution together with some more direct associative retrieval, which suggests a more complicated state of affairs than the Mayes et al. account. It does merit an attempt to discover if such single dissociations exist, as they would support the Mayes et al. hypothesis that associative recognition can be preserved via familiarity channels when other more complex contextual information is unavailable,

On the other hand, it is possible that inter-item associations make a direct contribution to temporal memory. Chaining models such as Murdock's (1995) TODAM chaining model propose that inter-item associations yield order information. There have been attempts to find relationships between serial and paired-associate learning, with mixed results (Young, 1968). However, studies have not attempted to investigate these processes together in neuropsychological patients. It is possible that although other mechanisms are involved in temporal context memory, inter-item associations are nonetheless a contributor to accurate judgments. Should a relationship be found between associative recognition deficits and temporal context deficits, this would merit a closer examination of the two abilities, in order to investigate the extent to which item-item associative mechanisms may form a foundation for making some types of temporal context judgments.

These general findings of impairments in forms of contextual memory tasks in amnesia has lead Mayes (1992; Mayes, Downes, Shoqeirat, Hall, & Sagar, 1993; Mayes, Meudell, & Pickering, 1985) to put forward a contextual memory deficit hypothesis (CMDH). According to this all amnesia is the consequence of a primary deficit in contextual information processing.

The review presented above suggests an unclear picture with regards to the relationship between temporal context, spatial context and associative recognition. These measures of context — temporal, spatial, and associative recognition — could display six different patterns of impairment, shown in Table 5.1. Different patients could show different outcomes.

The implications these outcomes have are summarised below.

1. This outcome suggests that temporal memory depends neither upon a generalised “context”

Tab. 5.1: Possible patterns of performance across three context tasks where + denotes normal performance, – denotes impairment.

Temporal	Spatial	Ass. Recognition	Outcome
+	–	–	1
–	+	+	2
+	–	+	3
–	–	+	4
+	+	–	5
–	+	–	6

that also supports spatial memory, nor the associative familiarity processes underlying associative recognition. This is good evidence for a dedicated system.

2. This outcome may suggest that temporal context is simply a more difficult task than the others, or, if coupled with cases exhibiting outcome 1 are present, form part of a double dissociation, good evidence for a dedicated system.
3. This outcome would be consistent with the Mayes et al. (2004) account of associative recognition, as although more complex contextual information (spatial) is lost, associative recognition is preserved, possibly via reliance on familiarity. It would also suggest that temporal memory may rely on inter-item associations, rather than a conception of context or source which includes spatial memory in its definition.
4. This outcome would similarly support the Mayes et al. account, but in addition suggest that inter-item associations are not sufficient to allow accurate temporal context judgments.
5. This outcome would imply that context memory and associative recognition are indeed underpinned by different processes, but in contrast to Mayes et al., the process that underpins associative recognition is more, rather than less, vulnerable to disruption — suggesting it does not rely on a process such as familiarity.
6. This outcome suggests that temporal context may depend upon the same mechanisms as associative recognition, rather than the same mechanisms as spatial context, and that these mechanisms are more vulnerable to disruption. This would be consistent with a role for intra-item association in temporal context, but inconsistent with the Mayes et al. hypothesis on associative recognition.

An examination of a patient case study allows opportunity to explore which of these outcomes may emerge under various conditions of neuropsychological impairment. Clearly, some outcomes

carry more weight in their implications; for example, evidence of double dissociation presents a more compelling case than evidence of co-morbidity of impairments.

Different tests of temporal context may tap different memory resources

A second issue this experiment will address is that of the use of various types of temporal memory task. Specifically, is recency comparable when tested using within-list and between-list approaches? Temporal memory is often assessed using a variety of tasks as documented by Mayes, Isaac, Holdstock, Hunkin, and Montaldi (2001), some of which are concerned with the ordering of items with a list and others with discrimination between lists. It is unclear whether these are all tapping the same ability. Mayes et al. (2001) argue that tests of recency are intrinsically suspect because they could in principle be solved by a reliance on familiarity - the test is not process-pure.

It is the case that amnesics under certain conditions appear to make recency judgments on the basis of trace strength or familiarity. Huppert and Piercy (1976) originally demonstrated that repeated exposure to items lead to false judgments that they were recently seen. This would be problematic if such performance were truly artefactual — that is, under normal conditions such information sources are not employed by the cognitive system, such that the performance we are examining in neurological patients can tell us little about the normal function of the mind. However, there is evidence that such distance-by-proxy solutions may be employed under certain conditions by normal participants to solve temporal judgments, such as with unfamiliar item (Chalmers, 2005; Dennis & Humphries, 1998) or under speeded conditions (Kemp & Burt, 1998), and some researchers (such as Friedman, 2001) argue that such information sources may be involved in the reconstruction of the relative position of items, even if they are not the sole determinant: Such claims have already been made in Chapter 3.

Due to this it begs the question to prohibit a test because performance could benefit from familiarity, as this may be a resource employed by the healthy human cognitive system for such judgments. Friedman (2001) argues that both reconstructive- and familiarity- (distance) based processes may be available but used under different conditions.

However, it remains that there may be means by which a memory-impaired patient may pass a test of temporal memory by using an alternative strategy to that available to normal individuals. Specifically, if such a patient brought to bear upon a temporal judgment task a strategy that was

not available in the healthy cognitive system, their performance could consequently be considered artefactual. Similarly, if a patient fails a task because of additional unintended task demands this renders the task suspect. Mayes et al. (2001) are correct to encourage us to take a more critical stance towards the temporal memory tasks we employ.

I have suggested in Section 1.4.1 that the judgment of recency task is a good way of tapping the processes that underly temporal judgments. It serves a functional purpose both now and has analogues in how we would solve tasks across our evolutionary past, such as monitoring the status of food caches (Clayton et al., 2003) or judging the causality of two events (McCormack & Hoerl, in press). It is particularly temporal in nature, unlike tasks of list discrimination where the judgment can be seen as one of affiliation or membership of a category — in other words, a test of source of information, achieved in a similar way to affiliation to a red-inked or blue-inked list. It does not introduce additional task demands such as organisation of large amounts of information, such as the sequencing tasks used in some studies (e.g., Shimamura et al., 1990).

However, this task, under certain conditions, may be vulnerable to a strategy that is only available to the abnormal memory system. This strategy would be enabled under conditions where the patient possessed a rapid forgetting rate, such that early items were entirely or nearly forgotten but recent items were relatively available. Dennis and Humphries (1998) use the term *generalised strength* to refer to a context-free amalgamation of a number of qualities including frequency, recency and duration of presentation. If generalised strength were to show a decay rate in certain patients that was rapid and qualitatively different to that found under normal circumstances, this could result in early items having little or no generalised strength at the time of test. Under these circumstances, judgments could be made as to the more recent item based upon a rejection of the item without generalised strength. Although this heuristic may be used by healthy participants from time to time it cannot explain temporal judgments in the main, as it would mean for example that internally cued memories could not be ordered, which is clearly at odds with our experience.

Investigators of episodic memory in patients may be at risk of this artefact due to the popularity of tests, such as list discrimination, that require judgments made upon lists displaced in time; should the earlier list be presented at a sufficient distance from the time of test, this would lead to forgetting of the first list members (a loss of generalised strength) and an intact memory for second list members. One way to ward against this is to employ a backsorting technique wherein list discrimination judgments only contribute to the analysis if the item had first been correctly recognised: this process is used in numerous studies (Bowers et al., 1988; Kopelman et al., 1997;

Mayes et al., 2001). However, in principle more may be required than this step. A patient could only recognise those items from the second list (because earlier items were forgotten), and always respond “List 2” to every remembered item in order to achieve a perfect temporal context score. Consequently, a tendency to forget earlier items (thus reducing the number of judgments made upon them) accompanied by a response bias to say “List 2” would inflate accuracy scores through the use of this heuristic not available to healthy participants under normal conditions. Investigators appear to have been aware of this, but it remains an implied guideline rather than an explicit ruling, such as an exclusion criteria based on participants response bias, hit and false alarm rate.

This experiment investigates whether some patients do indeed show this pattern of improved performance for list discrimination relative to recency memory. It uses two variants of the judgment of recency (JOR) — where two previously studied items are presented and the most recent must be selected — in order to match task demands as closely as possible. In one variant both items are from the same list (within-list recency) and one in which items are from two lists presented separated in time (between-list). The use of these tasks allows matching of response demands and presentation format. I am concerned that temporal memory judgments that involve discriminating lists rather than items may be more open to confound from other factors, namely the forgetting of items from the earlier list. Such forgetting would lead in my task to correct selection of the most recent item, by dint of it being the only one remembered, and in the standard list discrimination task lead to the correct attribution of “List 2” to remembered items and the correct attribution of “List 1” to forgotten items. If this procedure demonstrates that amnesic patients can show a dissociation between these two forms of recency memory in the direction suggested, this suggests that forgetting may in fact be aiding these judgments, which would inform future experimental design.

In summary, this experiment will investigate the following issues:

- Does recency dissociate from other types of source and context memory, such as memory for spatial position and associative memory such as paired recognition? Outcomes 1–6 above provide us with theoretical implications of patterns of performance.
- Is recency comparable when tested using within-list and between-list approaches? This investigation may shed light on possible ways in which amnesics may solve temporal context tasks by recourse to means unavailable to the normal cognitive system.

In order to investigate this, a test is used which has been devised to ensure that task and response demands are as similar as possible across these components. Study of a stimulus list is followed by trials probing all three measures. Titration is not used, as some researchers argue this produces a disproportionate effect upon familiarity, which may underpin one of the abilities (associative recognition) under investigation. This experiment thus attempts to investigate these issues without titration with the intention of providing convergent evidence with findings achieved by these methods.

Method

Participants

A case series of patients were recruited over the course of a year from March 2004.

Inclusion Criteria. Inclusion in this case series required patients to demonstrate memory impairments on behavioural testing. A neurological basis for memory-impairment was required as a diagnosis.

Exclusion Criteria. Exclusion in this case series was on the basis of a diagnosis of dementia, or any major cognitive deficits, such as aphasia, which would unduly affect their performance. Individuals with severe behavioural problems that would lead to lack of cooperation were similarly excluded.

Eight patients in all were recruited, from a variety of aetiologies. These are described individually below.

PP In the autumn of 2002 this patient began to experience an abnormal smell following which she became dysphasic and complained of a severe headache accompanied by nausea. Following an MRI scan and clinical examination a diagnosis of herpes encephalitis was made; this (2002) and a subsequent (2004) scan showed signal alteration in the left anterior medial temporal regions which was constant over time.

DH This patient underwent surgery in 1997 to remove a grade 1 ganglioma from the right temporal lobe, which was detected following reports of seizures. In 2002 he entered into a status

epilepticus suffering 4 seizures in the space of 12 hours without regaining consciousness between them. Following this he showed a profound deterioration in memory; clinical reports refer to “a severe retrograde amnesia” which was densest “for approximately a year or so before the seizures in October 2002 [with] difficulties in retrieving memories for periods long before the 10-year period of retrograde amnesia postulated by [DH’s] family.” His MRI shows clear signal alteration in a region of the right anterior temporal lobe resulting from the surgery, and hippocampal atrophy on the right, which is felt likely to be in part the consequence of hypoxic damage suffered in 2002.

JY In early 2002 this patient suffered an episode of ventricular fibrillation secondary to Wolff-Parkinson-White syndrome, a syndrome in which pre-excitation of the ventricles causes feedback within the heart’s connecting tissue, leading to rapid heart rate. This episode caused hypoxic brain damage, specifically bilateral hippocampal atrophy, leading to an organic amnesic syndrome.

KH This patient suffered a subarachnoid haemorrhage and aneurysm which produced a left temporo-parietal infarct with lateral temporal involvement. Damage was lateral and primarily parietal. This produced a bilateral arteriolar occlusion leading to impaired vision, episodes of forgetfulness and difficulties with new learning.

RD In early 2002 This patient was admitted with Wernicke encephalopathy accompanied by gross ataxia, followed by a residual Korsakoff syndrome; this followed a history of heavy drinking.

DF In the context of a history of heavy drinking and previously subtle memory deficits, this patient was admitted in 2004 with Wernicke features and a memory which had substantially worsened. A diagnosis was made of Wernicke-Korsakoff syndrome. During the period of testing he confabulated, suggesting that his doctors were in fact his bank employees, and incorporating components of the tests presented to him into his autobiography (suggesting that he had been to Euro Disney when an IRA attack had occurred, following successive public event questions about IRA attacks and Euro Disney).

KK Following seizures, this patient was found to be suffering from a left frontal cavernoma in the summer of 2004, causing damage to medial frontal regions. The damage was localised as a left intraparenchymal haemorrhage. She suffered an initial post ictal psychosis accompanied by confusion which had settled prior to the period of testing.

JB This patient suffered damage to the left caudate and left ventromedial frontal lobe following

rupture of an anterior communicating artery aneurysm in 1984. This led to problems in organising his daily life and impaired memory, along with personality changes.

In addition, twenty control participants were recruited. This sample is not ideally age-matched to the patients, as ethical board requirements stipulated that controls must be collected prior to selection of patients. This was as a number of new tests were to be employed with patients (including several not reported here) and confidence in power analyses and task demands was required before permission was given to use these measures with a clinical population.

Psychometric measures

In addition to the experimental task, a number of background measures were acquired for both patients and controls. These standard neuropsychological tests were used to assess general cognitive function, and explanations for their purpose are given in Appendix E. The battery employed included several measures of executive function, measures of recall and recognition memory, and measures of IQ. In some cases fuller measures of IQ were obtained for patients for a clinical purpose, and these scores are presented when available.

Performance on this range of psychometric tasks together with age at time of testing is presented in Table 5.2.

As can be observed, this series of patients shows a range of memory performance, including two with performance that is not markedly impaired, KK and KH. KHh shows middling to poor performance on the Logical Memory task, whereas KK does show problems with faces, but otherwise do not stand out on these standard measures. On the other hand, patients such as DH, PP and RD show more pronounced memory deficits, and JY and RD are extremely impaired. This offers us a range of neurological patients who report problems with memory, which heightens the possibility that the experimental tasks employed may pick up subtle or unexpected effects.

Relative to the control group

Using the approach suggested by Crawford and Howell (1998), each patient was compared against control performance for several tests, using the following formula

Tab. 5.2: Psychometric scores for patients.

Task	PP	DH	JY	KH	DF	RD	KK	JB
Age	57.3	61.4	27.8	58.3	60.5	60.5	30.1	60.0
<i>Measures of IQ</i>								
Estimated IQ (NART)	95	117	107	93	112	99	79	117
WASI VIQ	75				95			114
WAIS Vocab scaled score (SS)		14	10	9		9	6	
WASI PIQ	95				109			
Ravens SS		16	8	25		8	16 [¶]	
<i>Executive tests</i>								
FAS	22	39	22	27	14	20	18	33
Cog Est errors	6	3	9	0	6	11	9	3
Trails A percentiles	10–25	25–50	<10	25–50	10–25	<10	<10	norm
Trails B percentiles	10–25	75–90	<10	<10	<10	<10	<10	norm
Brixton	21	23	15	22	25	34	18	
WCST categories								6
<i>Memory</i>								
Digit Span	13	15	15	15	-	14	16	
Logical Memory I	9	18	5	20	6	18	25	
Logical Memory II	6	4	0	18	0	5	19	
Camden RMT Words percentiles	<5	50	<5	75 [§]	2 [§]	<5	90	30 [§]
Camden RMT Faces percentiles	90	25–50	<5	<5th [§]	2nd [§]	<5	25	39 [§]

[¶] Performance measured with Matrix Reasoning subtest from WASI

[§] Performance measured with Warrington RMT test

Tab. 5.3: Control psychometric scores for Experiments 9–10.

Task	Control Mean	Control S.D.
Age	73.2	7.5
Estimated IQ (NART)	116.6	4.9
WAIS Vocab scaled scores	15.3	2.4
Ravens	8.6	1.8
Digit Span Forward	18	5.7
FAS	51.1	11.1
Cognitive Estimation errors	3.7	2.7
Trailmaking A time	45.3	13.5
Trailmaking A percentiles	75–90	
Trailmaking B (time)	91.8	33.4
Trailmaking B percentiles	75–90	
Brixton	20.1	9.6
Logical Memory I	30.2	6.46
Logical Memory II	26.1	8.1
Camden RMT Words	24.5	1.2
Camden RMT Words percentiles	50–75	—
Camden RMT Faces	23.9	1.5
Camden RMT Faces percentiles	50–75	—

$$t = \frac{X_1 - X_2}{S_2 \sqrt{(N_2 + 1)/N_2}} \quad (5.1)$$

where X_1 is the individual's score, X_2 the mean score in the normative sample, S_2 the standard deviation of scores in the normative sample, and N_2 the number of people in the normative sample. .05 is considered the p-value cut-off. All patients were impaired at both components of the Logical Memory recall measure except patients KH and KK; previous testing showed JB to be below the 10th and 1st percentile for the immediate and delayed components. All patients were impaired at the FAS fluency task except for DH and JB. Only three patients were significantly impaired for Cognitive Estimates: JY, RD, and KK.

Design and Procedure

All participants performed the Temporal, Spatial and Associative Recognition Context Task (TSARC). This test measures the ability to make different types of memory judgments on presented stimuli. These are judgments of recency (both within-list and between-list), judgments of spatial location, associative recognition, together with a subsequent test of old/new recognition. These judgments are made upon the same studied material in order to assess relative competencies given information encoded at a uniform standard. Appendix F details the items that comprise each run, foils for the recognition tasks, and the composition of each judgment trial.

This test is composed of four runs, administered across two sessions. Overall session breakdown is depicted in Figure 5.1. The breakdown of each run is outlined in Figure 5.2.

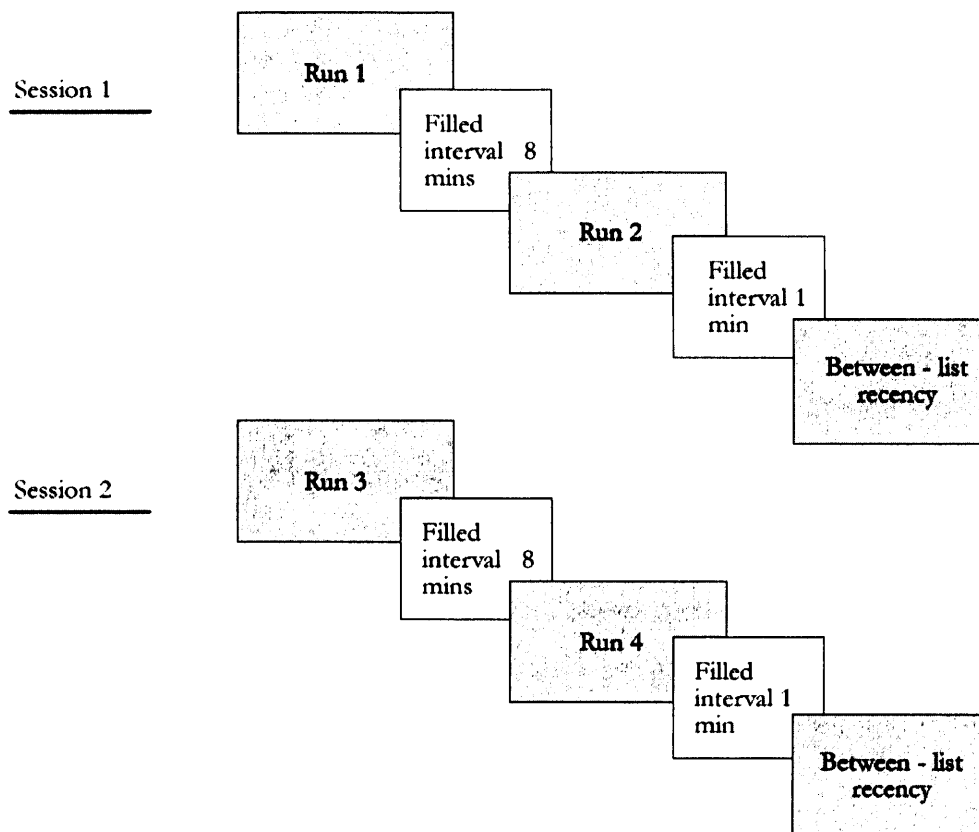


Fig. 5.1: Overall session breakdown for TSARC task.

Each session proceeds as follows. The subject is informed they will be presented with a number of cards each presenting them with two words. They are required to remember as much as they can about what they see. The subjects are asked to adopt an intentional encoding strategy of

visualising the contents of each card as it is displayed, such as imagining a scene containing both a “monk” and a “carpet”. Pilot data suggested that this test is quite demanding in the absence of mnemonic strategies, and this also provides some control over strategic and attentional differences between groups. Following this, the run of eighteen cards is administered sequentially at a rate of one every five seconds. Each card displays two nouns, one item at the top and one at the bottom of each card. After this study phase, a mixed test phase follows in which subjects have to make

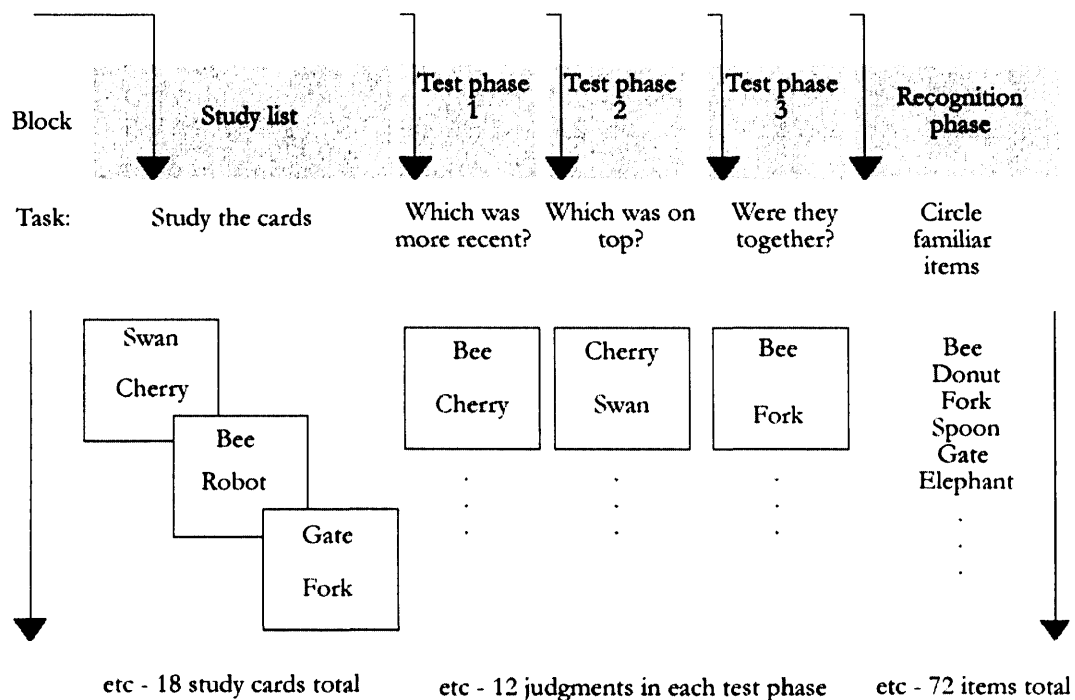


Fig. 5.2: Progression of each run in the TSC task.

three types of judgment in series upon what they have studied. This phase is blocked into three sections: a temporal context block, a spatial context block and an associative recognition block, which proceed in this fixed order, similar to Huppert and Piercy (1976). Throughout this test phase the response demanded of the participant is held constant, with subjects making a forced choice response between two possibilities. In each case they are presented with a series of cards which state the judgment, together with two words which have been seen before in the previous study phase. Twelve trials are presented for each judgment.

In the temporal context block, participants must select the item which was presented more recently (a judgment of recency). In the spatial context block participants must select the item which was originally seen on the top of the card (a judgment of spatial context). In the spatial context block participants must decide whether the pair were previously seen together or not, with

their response being a “yes” or “no” (a judgment of associative recognition memory).

Following these trials, 36 in all, subjects are given an old/new recognition test, where they must pick all the words they remember seeing from a large list which contains the thirty-six words from the study list, alongside an equal number of new words. It should be noted that this methodology results in high recognition rates as subjects are exposed to targets once at study and twice further in the test phases before they are presented in this recognition test. This is unavoidable, as the other measures taken are vulnerable to disruptive interference if shown repeatedly.

This concludes a single run. Following the first run of a session, a filled interval of eight minutes is presented, within which a distractor task is employed. Subjects then undertake the second run, which is identical in procedure but contains a new set of words. Following completion of this, there is a filled interval of one minute during which basic biographical information is taken from the subject. After this a final test phase takes place, which in format is identical to the JOR trials given earlier, except that in this case one word is always from the first list and one from the second. This provides a test of between-list JOR, or list discrimination. It should be noted here also that the items being discriminated have all been viewed repeatedly, but that the repeated viewings have not overlapped, in that target item (from the second run) presentations have all been more recent than distractor item (from the first run) presentations. The between-list JOR task involves twelve trials.

Across the four runs 48 judgments are made of each of the following: within-list temporal context, spatial context and associative recognition. 24 judgments are made of between-list temporal context. An old/new recognition task is administered for each of the four study lists, each composed of 36 targets and 36 foils.

Results

The old/new recognition task that follows the contextual measures may offer some indication of overall item memory for the items presented. A d' score was calculated for each patient and across controls; these are shown in Table 5.8. The number of errors for each task was collated for each control and patient. One control subject attained a score of well below chance for one measure, suggesting misunderstanding of the task requirements, and their data was removed from analysis. Accuracy for each measure for patients and control mean is also presented in Table 5.8.

Tab. 5.4: TSARC Recognition measures and context memory accuracy scores for patients and controls.

Measure	Control	Temporal —(t)				Korsakoff — (k)		Frontal —(f)	
		PP	DH	JY	KH	DF	RD	KK	JB
Recognition d'	4.11(.96)	1.26	3.58	-0.11	4.11	0.28	1.14	4.27	1.05
Recognition hits	.92(.09)	.51	.81	.11	.92	.72	.51	.94	.83
Recognition FA	.02(.04)	.11	.00	.14	.00	.62	.14	.00	.46
Within-list recency	.74(.10)	.46	.60	.60	.58	.42	.48	.56	.40
Spatial context	.76(.12)	.50	.60	.38	.73	.52	.46	.71	.56
Associative recognition	.88(.13)	.71	.88	.54	.92	.54	.56	.65	.56
Between-list recency	.69(.16)	.71	.71	.46	.54	.38	.42	.88	.50

Chi-square analysis of the recognition data suggested that all patients were performing discriminations better than chance, except for patient JY, $\chi^2 = .32, ns$ and borderline for patient DF, $\chi^2 = 3.25, p = .07$.

Using a range of measures that are differentially demanding makes it hard to evaluate relative sparing and impairment with untransformed scores. Accordingly, the Crawford and Howell (1998) formula was used to convert each patient score into a t-value, allowing patient performance to be assessed in terms of their degree of deviation from control performance. With 18 degrees of freedom (based upon the control sample n), t-values of 1.73 fall at the .05 significance level. Scores that fall below -1.73 or greater will consequently be considered impaired. Performance is shown graphically in Figure 5.3. Due to a high variability for the controls on the between-list recency task, the cut-off for this measure falls below actual chance (12/24). As a consequence, it should be noted that for this measure, t-values of -1.15 or below represent chance performance in real terms.

A number of observations can be made from this. Patient JY shows considerable impairment with spatial memory but is relatively spared at within-list recency. He is at floor at between-list recency. Patients KK and KH show a trend towards the opposite pattern with unimpaired spatial performance coupled with a more severe problem with within-list recency, albeit one that in neither case reaches the threshold value of 2. In the case of KK, this is coupled with a clear sparing of between-list recency, her positive t-value denoting performance superior to the control mean. A more striking example of this can be seen in patient PP, who is clearly and substantially impaired at within-list recency, scoring at floor, whilst showing normal between-list performance. Three patients, DF, RD and JB, are effectively at floor across all measures.

In subsequent sections, where a patient displays disparate levels of impairment across tasks the degree of abnormality is calculated using a method outlined in Crawford, Howell, and Garthwaite (1998), which uses information about the correlation across tasks and standard deviations for the

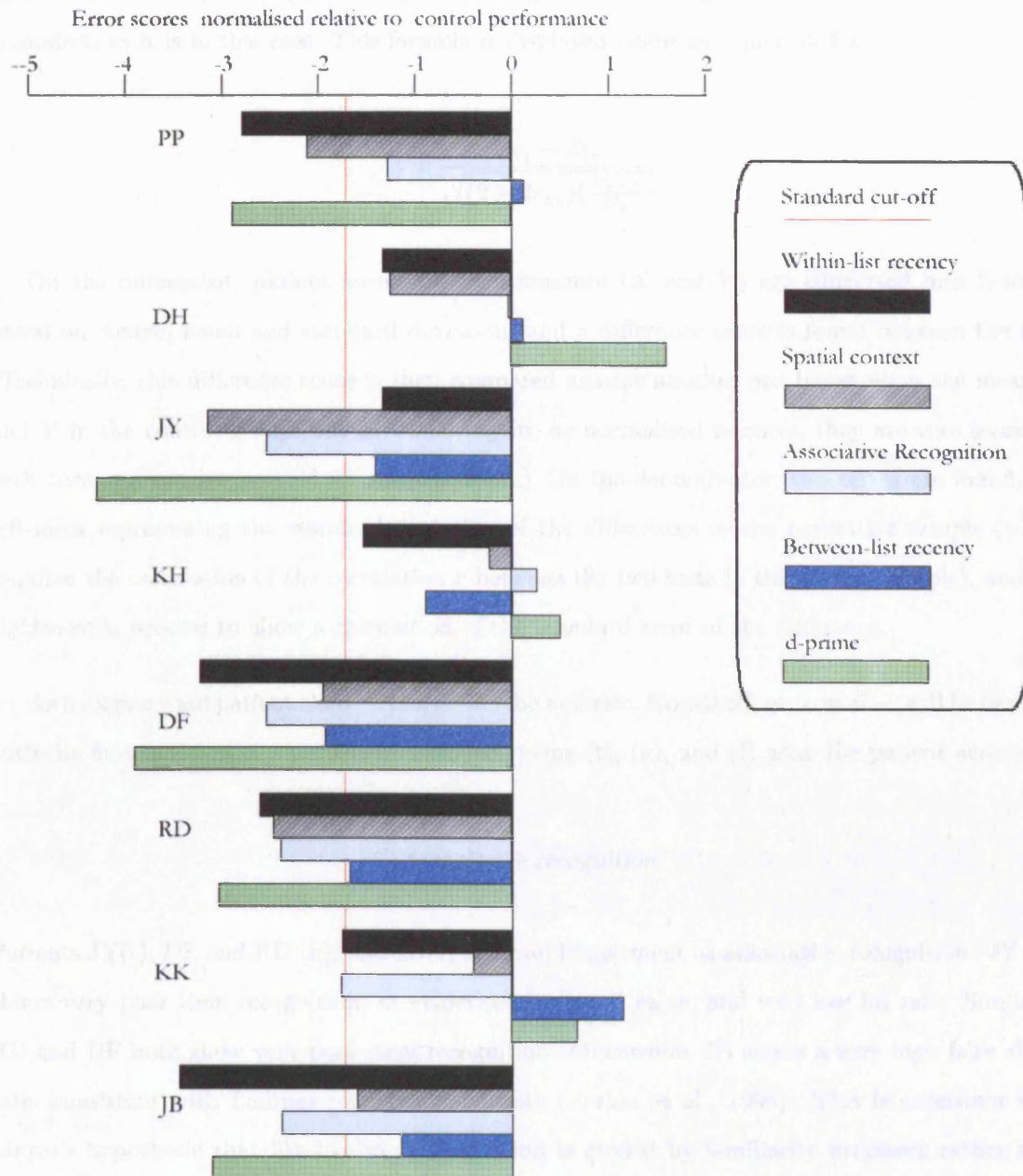


Fig. 5.3: Level of patient performance on various context tasks in terms of t-values. Red line depicts .05 significance level on the basis of t-values and sample n ; however, t-values falling at or below -1.15 or greater actually reflect floor performance for the between-list recency measure.

control group together with deviation scores from a single case to determine how common said score is within the population at large. In using control data as a sample statistic, this method offers an advantage over the earlier technique of Payne and Jones (1957) which treated it as population parameters, with the consequence of systematically overestimating abnormalities when sample size is modest, as it is in this case. This formula is displayed below as Equation 5.2.

$$t = \frac{Z_{X_1} - Z_{Y_1}}{\sqrt{(2 - 2r_{xy})(\frac{N_2+1}{N_2})}} \quad (5.2)$$

On the numerator, patient scores on each measure (X and Y) are converted into Z-scores based on control mean and standard deviation, and a difference score is found between the two. (Technically, this difference score is then compared against another one based upon the mean X and Y in the control group, but as would, again, be normalised z-scores, they are zero scores in each case and can be omitted for simplification.) On the denominator, two terms are found, the left-most representing the standard deviation of the differences in the normative sample (which requires the calculation of the correlation r between the two tests in the control sample), and the rightmost is present to allow a calculation of the standard error of the difference.

As a memory aid patient class — temporal lobe amnesic, Korsakoff, or frontal — will be denoted with the first mention of a patient in a section, using (t), (k), and (f) after the patient acronym.

Associative recognition

Patients JY(t), DF and RD (k), and JB(f) show an impairment at associative recognition. JY also shows very poor item recognition, as evidenced by his d' value, and very low hit rate. Similarly, RD and DF both show very poor item recognition. Meanwhile, JB shows a very high false alarm rate, consistent with findings reported previously (Parkin et al., 1996). This is consistent with Mayes's hypothesis that like-like item association is guided by familiarity processes rather than recall (Mayes et al., 2004) - all subjects show poor old/new recognition in which familiarity plays a substantial role. JY's poor associative recognition can be contrasted with a relatively less impaired score for within-list recency. Use of Equation 5.2 reveals that abnormalities of performance at or beyond this level could be expected within 9.1% of the population.

One patient, KK(f), shows moderate impairment for this task but her t-value does not exceed the cut-off. It is worth noting that despite this moderate impairment, KK shows no signs of

disruption of familiarity processes, as illustrated by her high hit rate and lack of false alarms. Such deficits have been reported before in patients with frontal involvement, but are normally accompanied by spatial context deficits (Petrides, 1982) or temporal memory deficits (Vriezen & Moscovitch, 1990). KK performs normally for the spatial context component, normally for list discrimination and is impaired to a similar extent for within-list recency memory. It is worth noting that of the five patients considered impaired at within-list recency, only one — PP(t) — is unimpaired at associative recognition. Using Equation 5.2 reveals that a deviation between scores of this magnitude in either direction could be found in just over 13% of the population.

Spatial and temporal context

Considering within-list recency and spatial context, three patients show impairments at both tasks: DF and RD (k), and PP(t), and three patients score better than cut-off on both tasks: DH(t), KH(t), and KK(f). JY(t) is extremely impaired at spatial context but shows relatively spared performance at within-list recency, although he is at floor for between-list discrimination. The mismatch between spatial and within-list recency is fairly high in the context of the normal population, with only 7.0% of the population expected to produce more extreme deviations between scores. JB is impaired at both tasks of temporal context, whereas he shows a moderate impairment at spatial memory that falls below the cut-off. Of all patients impaired at a temporal memory task, his is the mildest spatial memory deficit; that is, all patients with temporal memory deficits showed mild or greater impairments in spatial memory. Use of Equation 5.2 reveals that this deviation between within-recency score and spatial score would be expected in only 6.9% of the population.

Within-list recency and between-list discrimination

Three of the four patients impaired at within-list recency also show a decrement at between-list discrimination: DF and RD (ks), and JB(f). JY(t) is somewhat impaired at within-list recency but at floor for between-list recognition. PP(t) is impaired at within-list recency but performs normally at between-list discrimination. This deviation between scores would be expected in only 4.0% of the population. There is a similar trend at work in KK(f), who is somewhat impaired at within-list recency (but not at cut-off) but better than control mean for between-list discrimination. This pattern is similarly rare in the population, with only 4.1% exhibiting a difference more extreme than this one.

Correlations

Correlations between the various context memory tasks, as well as for a number of psychometric measures (Frontal scores: verbal fluency, Brixton test, Trail Making, Cognitive Estimates; Memory Scores: Spatial Span, Logical Memory recall task, d' recognition performance on context task), were computed for the patients, using Spearman's Correlation Coefficient as groups were small. Spatial context showed a relationship with d' , $r_s(8) = .714, p = .047$, and Associative recognition showed a relationship both with d' , $r_s(8) = .868, p = .005$, and with Between-list recency, $d', r_s(8) = .715, p = .046$. Between-list recency additionally showed a relationship with performance on the Trailmaking task, $d', r_s(8) = -.829, p = .021^2$. The full table of correlations are presented in Table 5.5.

Tab. 5.5: Correlations between context memory measures, general memory measures and frontal scores within patients

	Within-recency	Spatial context	Assoc Recog	Between-recency
Spatial context	.084	—	—	—
p-value:	.844	—	—	—
Assoc Recog	.321	.699	—	—
p-value:	.438	.054	—	—
Between-recency	.307	.563	.715*	—
p-value:	.459	.146	.046	—
d-prime	.347	.714*	.868†	.802
p-value:	.399	.047	.005	.017
Brixton	-.432	.036	.018	-.541
p-value:	.333	.939	.69	.210
Trail-making	-.234	-.643	-.631	-.829*
p-value:	.613	.119	.129	.021
Cognitive estimates	.024	-.655	-.583	-.232
p-value:	.954	.078	.129	.581
Spatial span	.585	.714	.595	.523
p-value:	.222	.364	.954	.393
Logical memory	.054	.714	.595	.523
p-value:	.908	.071	.159	.229

* Indicates a significant correlation at .05

† Indicates a significant correlation at .01

Correlations were conducted separately for controls. These revealed relationships for only two of the experimental tasks. A significant relationship was found between spatial context t-value and d' , $r_s(19) = .691, p = .001$. Associative recognition t-value showed a relationship to

² Note that the negative correlations observed in with Trailmaking task simply reflects the fact that the measure (time to completion) is greater when an individual is poor at the task.

$d', r_s(19) = .543, p = .016$ and to performance at the Logical Memory task, $r_s(19) = .564, p = .012$.

The full table of correlations can be observed in Table 5.6.

Tab. 5.6: Correlations between context memory measures, general memory measures and frontal scores within controls

	Within-recency	Spatial context	Assoc Recog	Between-recency
Spatial context	.406	—	—	—
p-value:	.085	—	—	—
Assoc Recog	.137	.419	—	—
p-value:	.577	.074	—	—
Between-recency	-.091	-.027	.228	—
p-value:	.711	.912	.348	—
d-prime	.272	.691 [†]	.543*	-.096
p-value:	.260	.001	.016	.696
Brixton	-.225	-.396	-.407	-.327
p-value:	.355	.094	.084	.172
Trail-making	-.421	-.220	-.124	-.179
p-value:	.072	.365	.613	.463
Cognitive estimates	.277	.124	-.286	-.125
p-value:	.252	.614	.235	.611
Spatial span	.423	.225	.399	-.067
p-value:	.071	.355	.090	.784
Logical memory	.073	.197	.564*	.254
p-value:	.767	.419	.012	.294

* Indicates a significant correlation at .05

† Indicates a significant correlation at .01

‡ Indicates a significant correlation at .001

Where correlations were at or toward significance in both groups and of a comparable size, a further analysis was done using the same groups, and again utilising Spearman's r_s for consistency. From considering Tables 5.5 and 5.6, it can be seen that the correlations between spatial context with d-prime and associative recognition meet this criteria, as do those for associative recognition with d-prime and logical memory, within-list recency and spatial span, and between-list recency and the performance on the Brixton task. In addition, as the issue of temporal memory and its relationship to other aspects of contextual memory is central to this thesis, correlations between the recency measures and other context measures were included, despite their lack of clear correlation in the patient group. These correlations were performed and are presented in Table 5.7; these proved significant except for the correlations of between-list recency with associative recognition, within-list recency and the Brixton task.

Finally, Equation 5.2 was used to produce a table depicting the relationships between d' and each of the context measures, in order to determine the degree to which impairments in one

Tab. 5.7: Selected correlations for patients and controls

	Within-recency	Spatial context	Assoc Recog	Between-recency
Spatial Span	.555	—	—	—
p-value:	.004	—	—	—
d-prime	.392*	.659 [†]	.637 [†]	—
p-value:	.043	.000	.000	—
Assoc Recog	—	.694 [†]	—	—
p-value:	—	.000	—	—
Logical memory	—	—	.712 [†]	—
p-value:	—	—	.000	—
Brixton	—	—	—	-.347
p-value:	—	—	—	.082

* Indicates a significant correlation at .05

[†] Indicates a significant correlation at .01[‡] Indicates a significant correlation at .001

accompany the other. This is depicted in Figure 5.8.

Tab. 5.8: Selected correlations for patients and controls. Percentage refers to percentage of population in which a discrepancy this size or greater would be expected.

Context Measure	PP	DH	JY	KH	DF	RD	KK	JB
Within-recency	.055	-2.356	2.343	1.647	.52	.328	-1.95	-.285
Percentage	48	1	2	6	30	37	3	39
Spatial	.914	-3.466	1.368	.927	2.325	.661	-1.339	1.78
Percentage	19	<1	9	18	2	26	10	5
Assoc Recog	1.588	-1.661	1.738	1.648	1.345	.63	-2.434	.705
Percentage	6	6	5	6	10	27	1	24
Between-recency	1.97	-.989	1.88	.936	1.285	.88	.299	1.266
Percentage	3	17	4	18	11	20	38	11

For convenience, where d-prime is superior to the context measure in terms of t-score the T-value for the discrepancy is prefixed with a negative sign; where context performance is superior the discrepancy is presented as positive. Half the patients showed discrepancies with within-list recency and spatial context that would be expected in under 10% of the normal population. Five of the eight showed comparable levels of discrepancy with associative recognition. Only two patients, PP and JY, showed a discrepancy of this magnitude for between-list recency and d-prime. These discrepancies occur in both directions, as evidenced by both negative and positive values in the table, although the majority of highly discrepant scores are cases where context performance is superior.

General memory performance, as measured by d' and recall memory ability, as well as one frontal lobe measure (Trailmaking) appear to be good indicators of level of context memory performance,

except for between-list discrimination where the relationship was marginal. The context memory measures also correlate with one another, with the exception of between-list discrimination, which did not correlate with the other measures.

Discussion

This experiment presents the performance of a case series of patients of mixed aetiology on a task which probes various aspects of memory: recognition memory, together with measures of spatial and temporal context, and associative recognition. It seeks to address how contextual memory deficits occur and whether they are dissociable or tend to cluster together alongside broader memory complaints. I shall try and address these issues below with respect to the findings from this task.

Associative memory appears to be poor when item recognition memory is also poor. This would be consistent with a disruption of processing that allows familiarity to be computed under the Mayes et al. (2004) hypothesis of associative recognition. The exception to this — KK, whose d' is above the control mean and also outperforms the other patients — is a borderline case who does not fall below above the cut-off for associative recognition t -values. One case, PP, is impaired at within-list recency but only shows a mild impairment in associative recognition, which may be inconsistent with the claim that intra-item associations are sufficient to underpin temporal memory. However, her pattern of performance was not abnormal by the use of the Crawford et al. (1998) technique. One case, JY, is mildly impaired at within-list recency in the face of a severe associative recognition impairment, and very poor d' which may be inconsistent with the claim that intra-item associations are necessary to underpin temporal memory. This pattern is not extremely abnormal in the context of the normal population, and may be questioned due to the subsequent lack of discrimination shown on an old/new recognition task.

In six of the eight cases an impairment in either spatial context or within-list recency accompanied an impairment in the other. Although the impairments co-occurred, there were discrepancies in their severity. One temporal-lobe amnesic case shows a greater impairment in spatial memory (JY) and one frontal case a greater impairment in temporal memory (JB). These mismatches in impairments can be considered abnormal by the Crawford et al. (1998) methodology. This is consistent with the previous literature which suggests a particular role for the hippocampus in spatial

and location memory (Abrahams et al., 1999), and a frontal role in selective impairment of temporal memory (Kesner et al., 1994). It does suggest, however, that impairments are not restricted to these lesion sites (Mayes & Daum, 1997), and that difficulties with one type of context memory often accompany the other (Kopelman et al., 1997). These measures show a trend to a relationship (bordering significance) within the control group but within our patient group no correlation was found. Given the small size of this group, little conclusions can be drawn from this.

Within- and between-list memory do not show a significant relationship and dissociations were found between the tasks in certain patients, KK and PP, although these are only single dissociations in one direction, with poorer within-list recency relative to between-list than would be expected in only 2% of the population (4% expected to produce more extreme disparities in either direction). This suggests that the two tasks are underpinned by different processes, or that performance is mediated by an external variable for one task.

In the current study, no frontal measure consistently correlated with performance in the contextual memory task, although Trailmaking showed a relationship to Between-list recency for the patients only. Measures of fluency, cognitive estimation and the Brixton task of visuospatial sequencing and flexible rule use showed no relationship to memory performance. This is consistent with the findings of Shaw and Aggleton (1995), who found “no clear evidence of a contribution of frontal lobe function to recency memory” (pg 63) using tests of fluency, cognitive estimation and the Wisconsin Card Sorting Test of flexible rule use. It is consistent with Kopelman (1989), who found no correlations between frontal measures and anterograde temporal context memory. It also follows Kopelman et al. (1997), who argue that their findings, together with the previous literature “indicate that context memory impairment seems to be more closely associated with a ‘core’ memory deficit in amnesic patients than with any concomitant executive or frontal dysfunction” (pg 1541).

General memory performance measured by d' and recall memory, appears to show a better relationship to context memory accuracy, particularly with associative recognition and spatial context. However, a number of patients show unusually intact spatial memory performance in the face of substantial d' deficits, as evidenced by use of Equation 5.2. This suggests that some aspects of spatial context can be maintained in the absence of general item memory.

Between-list recency showed a trend toward a relationship with d' in the patient group, but this was not significant and not reflected in the controls. The within-list measure similarly showed

little relationship. However, between-list recency performance was similar to d' performance as demonstrated by the Crawford method, whereas the within-list performance showed a split wherein half the patients, primarily with temporal lobe damage but including one frontal patient, showed little relationship between the two measures, whereas the other half showed comparable level of impairment for both tasks.

Shoqeirat and Mayes (1991) show a relationship between target memory performance and spatial memory, consistent with the present findings. Our lack of a relationship between recency performance and other tests of memory is consistent with Sagar, Gabrieli, Sullivan, and Corkin (1990). Similarly, Experiment 1 of Shaw and Aggleton (1995) shows no correlation between recency and the standard memory measures, and their Experiment 2 demonstrates a dissociation between recency and recognition, which is not uniformly observed in our study, but in terms of relative performance can be seen in four of eight instances.

On the other hand, Kopelman (1989) and Parkin et al. (1990) found that temporal context memory correlated better with target memory performance than with frontal performance in amnesic groups. Additionally, Kopelman et al. (1997) showed correlations between both temporal and spatial context and the levels of performance on the WMS-R general memory and delayed memory quotients. One of the reasons for this discrepancy may be the focus on between-list recency (which approached significance in our small patient group). In the current study, a relationship is found between context performance for non-temporal tasks and d' for the items previously used in the context tasks, something that Kopelman et al. is unable to show due to a titration procedure that aimed to fix recognition performance at a similar level across groups. These studies together with the current findings are consistent with the claim that context memory depends upon “core” memory rather than a dedicated contextual coding mechanism. However, this study does not provide compelling evidence that this classification includes temporal memory.

This experiment has a number of similarities in approach and findings to the Kopelman et al. (1997) paper, so it may be worth underlining the differences between the two. Firstly, the current study does not match recognition performance across patients, whereas the Kopelman et al. study attempts to do this using a titration procedure. Such a procedure is a widely used method of matching recognition (Hirst et al., 1986; see also Huppert & Piercy, 1976 examining temporal context) in group studies. This is a more difficult matter in a case series where corrections to titration cannot be made on the basis of performance of previous members of group/pilot data as the test subject necessarily belongs to a population of 1. Additionally, some researchers charge

that extended presentation of stimuli may have a disproportionate effect on some components of memory relative to others (Giovanello & Verfaellie, 2001); the convergence between some of the findings of this study with that of Kopelman et al. without using such a methodology increases confidence in the findings.

Secondly, Kopelman et al. used a measure of between-list discrimination, whereas the present study uses two measures of temporal memory, a within-list and a between-list recency task. In the present study, between-list recency showed little relationship to spatial memory or general memory performance, and so did not follow the pattern seen in Kopelman et al., whereas within-list recency did. This may reflect that fact that in Kopelman et al., recognition performance of patients was typically good (thanks to the titration procedure) and consequently some confidence can be had that temporal judgments following correct recognition were not influenced by the artefact discussed previously, of a response bias coupled with low recognition rates for items from the more remote first list. Meanwhile in the current study a two-stage judgment was not employed, and between-list recency shows a weak relationship to its within-list counterpart, with one case of clear dissociation on the tasks.

In summary, this experiment has found within-list temporal memory impairments to co-occur with impairments in other context memory. Within-list temporal memory co-occurs with either associative recognition or spatial context, and in cases where the latter two abilities are both intact or impaired within-list recency follows the same pattern, with the exception of patient JY for whom a conflicting pattern of data is shown; returning to the raw data, it appears on several runs this patient did score chance or near chance, performing a single run at a rather better level of accuracy, which does not seem to reflect “preserved” temporal context memory. This is consistent with a position where temporal memory and other forms of context memory are abilities emerge from fundamental features of memory rather than specific mechanisms.

Experiment 10: Estimation of time intervals and temporal memory

Temporal cognition is a thriving area of cognitive neuroscientific research (Block & Zakay, 1996; Gibbon et al., 1997), encompassing animal work (Hastings & Maywood, 2000), neuropsychology (Nichelli et al., 1996) and more recent techniques such as neurophysiological measures (Gibbons, Brandler, & Rammsayer, 2003) and brain imaging (Volz et al., 2001). A full summary of this research is beyond the scope of this thesis; it is sufficient to say that this area has generated much work to support the notion of temporal clocks, though there is still some controversy over how and where³ they are instantiated. It is known that in humans basal ganglia damage leads to underestimation of time in the short term (O'Boyle et al., 1996) and overestimation for longer intervals (Malapani et al., 1994). Damage to frontal cortex leads to underestimation of time intervals (Ivry & Keele, 1989) and variability is increased by damage to premotor frontal cortex (Lacruz et al., 1992). Pertinent to this thesis is how temporal cognition relates to memory, for which there is a far smaller neuropsychological literature, albeit one with deep roots. Korsakoff (1889/1996) commented on the tendency for his amnesic patients to suffer particularly greatly with temporal memory, an observation since endorsed by more modern commentators (Sacks, 1985; M. Williams & Zangwill, 1950), and Horst (1932) claimed that the comprehension of time was disturbed in these patients. M. Williams and Zangwill (1950) describe a patient for whom the experience of elapsed time appeared to be greatly slowed relative to ours, in that a minute felt like a quarter hour; a similar case is described in Becker and Sternbach (1953).

A different pattern is shown in Binkofski and Block (1996), who detail a patient (BW) who displays the *Zeitrafferphänomen* of accelerated time experience. Its more common cause is parietal-occipital damage, usually to the right hemisphere (Hoff & Pözl, 1988; Pözl, 1951 - but see Ahrens, 1943 for a case with left-lateralised damage), but in this instance was the consequence of damage to the prefrontal cortex. This study was the first to objectively assess duration estimation in a patient experiencing from this condition. They demonstrate that BW vastly overestimates the length of a 60-second duration nearly fivefold, with a mean produced duration of 286 seconds. His long-term memory was not assessed. In keeping with Benton, Allen, and Fogel (1964), who demonstrated that orientation to time and date is not correlated with time estimation, BW showed good temporal orientation. They suggest that his condition may be understood under the framework of scalar timing theories (Gibbon et al., 1984), by supposing that the telescoping of durations was due to

³ To be a little more specific there is broad agreement that the cerebellum is involved and much to support additional involvement of the basal ganglia (Ivry, 1996), but also evidences pointing to a role for the suprachiasmatic nucleus of the hypothalamus (Cohen et al., 1997) and systems distributed throughout the cortex (Rao et al., 1997).

“the pacemaker component of his internal clock...now producing pulses at a considerably decreased rate” (pg 491).

BW’s experience of time was accelerated, but did not appear to be *accelerating*, as “although BW’s mean production was abnormal, the variability of his productions was fairly normal” (pg 490). Such a state would act to preserve order relationships between items. This has implications with respect to some conceptions of temporal memory, specifically, a divergence in predictions between pure positional models and temporal discrimination models. Positional models would predict that individuals in this state, or its converse, would not show particular impairments in temporal memory. Following Binkofski and Block’s explanation, individuals with an accelerated time experience possess a pacemaker that is operating more slowly, and contributing “ticks” to an accumulator at a slower rate. A temporal discrimination theory where order memory is achieved through the comparison of temporal codes that record the contents of an accumulator at the time of encoding, such as G. D. A. Brown’s SIMPLE model, would require that Zietraffer patients perform poorly at tests of order memory because for any two given events, their temporal codes will be far more similar (fewer accumulated pacemaker “ticks” to distinguish them) than for the normal population. Conversely, individuals experiencing widening time could be expected to show superior performance if the basis for this experience was the speeded action of a pacemaker.

Under the scalar timing model, patterns of performance other than telescoped time perception could be produced by damage to the oscillator system. A generalised, non-directional impairment in time perception could be the consequence of a pacemaker losing regularity, or damage to the accumulator making its recording sporadic. The exact mechanisms are unimportant, as they would all have similar implications for temporal discrimination models — an unreliable time-code that would lead to impairments in temporal discrimination. Consequently, the temporal discrimination models that rely on time codes formed from the operation of scalar timing systems predict impaired temporal memory performance in cases where time estimation is generally poor, and cases where time is experienced at an accelerated rate, and superior performance in cases where time is experienced at a decelerated rate.

Positional models would predict no difference in performance on the basis of accelerated or decelerated time; nor if time estimation was generally poor - an exception to the latter would be in the case that conscious awareness itself were actually disordered as a consequence, such that events A,B,C were experienced as A,C,B, but this would not be implied by a deficit in time estimation alone, particularly if the scalar timing explanation holds. Contextual models would likely predict

the same as positional ones, but this would depend somewhat upon what effect the phenomenal state of the patient has on cognition - if patients suffering from accelerated time are only aware of a fraction of their experience then a contextual account might suggest such patients have not the opportunity to connect events to a contextual frame.

Richards (1973) conducted an earlier study that speaks to this issue. He investigated the time reproduction ability of the well-known patient H.M., the case of Scoville and Milner (1957) who after undergoing a surgical removal of bilateral medial temporal cortex become profoundly amnesic. Richards used a task in which H.M. had to delineate a specific period of time, by saying "stop" after a stopwatch was begun, equivalent to a previously presented period which the experimenter both began and ended with a "start" and "stop" respectively. H.M.'s performance was normal for intervals of less than 20 seconds, but for intervals exceeding 20 seconds he consistently underestimated the passage of time. Richards extrapolated from his data to suggest that "one hour to us is like 3 minutes to H.M.; one day is like 15 minutes; and one year is equivalent to 3 hours for H.M." (pg 281). Underestimation in this manner has been observed in other amnesic patients (Nichelli, Venneri, Molinari, Tavana, & Grafman, 1993).

Subsequent work has shown that H.M. performs normally on tests of verbal and non-verbal recency (Petrides & Milner, 1982; Sagar et al., 1990). Given the explanation posed by Binkofski and Block (1996) for substantial underestimation of time - of the slowing of an accumulator - this has implications for theories of temporal memory. Temporal discrimination hypotheses that depend upon accumulated pacemaker ticks would predict H.M.'s temporal memory to be poor; given that it is not, even in the face of generalised impairments of memory, this case speaks against the theory.

Shaw and Aggleton (1994) investigated the ability of amnesic patients to estimate time intervals from three to ninety-six seconds, using an adapted version of the Richards (1973) paradigm. Their task required participants to say "stop" after a stopwatch was begun to delineate a specific period of time, which was either a declared period stated in seconds, or an experienced period preceding the test in which the experimenter both began the period with a "start" and ended it with "stop" once the time had elapsed. They demonstrate that amnesics suffering from Korsakoff's syndrome were impaired at all intervals whilst their Post-Encephalic group performed normally. The pattern found in Richards (1973) of abnormal estimation for intervals greater than 20 seconds was not observed. Shaw and Aggleton suggest that this may be due to differences in analysis; those authors employed measures of absolute error, which they demonstrate captures abnormalities in estimation of shorter periods for the Korsakoff group that would not be seen in matching true time against estimated

time, the procedure used by Richards (1973). Effectively, they are demonstrating a generalised impairment in time estimation (under- and over-estimation) which would be hidden by analysing direction of error. Those authors followed this up with an investigation of recency and recognition memory using groups composed of the same patients (Shaw & Aggleton, 1995). Using JOR pairs with 0,1,4 or 5 intervening items, they revealed a similar degree of temporal memory impairment in both groups, which was unaffected by changes in lag⁴.

The above findings suggest that temporal duration judgments and temporal order memory are dissociable under certain conditions. H.M. performed normally on tests of recency (Petrides & Milner, 1982; Sagar et al., 1990) but showed impairments in time estimation, whilst Shaw and Aggleton's Post-Encephalitic patients (1994, 1995) were as a group impaired on tests of recency but showed normal time estimation. A stronger case for double dissociation could be made if a single case was provided with the reverse pattern to H.M., rather than a dissociation in overall group performance. In examining performance on both tasks together in those participating patients, I intend to investigate whether such dissociations exist.

It may also be that despite the findings of Shaw and Aggleton and H.M.'s pattern of performance, there is a pervasive relationship between time estimation and temporal memory. It may be the ability to order and judge relative position of items depends upon their temporal discriminability which itself depends upon the accurate working of oscillator systems. If so we would expect the accurate working of such systems to manifest itself in greater accuracy in temporal estimation, and hence predict that good performance in this task should accompany good temporal memory performance, whereas errorful temporal estimation should accompany poor temporal memory performance. We should therefore expect performance in healthy controls to show these patterns, and where patient performance differs from these patterns require a plausible auxiliary hypothesis to explain it.

Of the 8 patients involved in this task, none of them reported a sense of speeded or slowed time. In the case of one patient, DF, spontaneous confabulations were observed which had a flavour of temporal displacement about them; however, there is current controversy over the issue of whether displaced incidents in confabulation can be considered temporal displacements (Moscovitch & Melo, 1997).

⁴ This runs contrary to Hunkin and Parkin (1993) wherein Korsakoffs patients performed worse than Post-Encephalic amnesics.

Method

Materials and participants

The same patients and control participants are used as those outlined earlier. The temporal estimation task, which required a stopwatch and a double-sided notice which stated “I am timing ([Name of experimenter])” on one side and “Tell me when to stop” on the other.

Design

Participants were to estimate the lengths of six different time intervals, of 3,6,12,24,48 and 97 seconds. This follows the design of Shaw and Aggleton (1994). The set of intervals were estimated on two separate occasions.

Procedure

Participants were briefed as to the nature of the task. They were told they would be exposed to an interval of time, and then asked to reproduce that interval. A notice would be present to remind them of what their current involvement in the task was. It was stressed to all participants that they should avoid counting or marking time in any way such as telling and retelling a poem or story, as the experiment was concerned with the sense of time that came naturally; that instead they should simply relax. The source of any regular temporal information, such as a clock or watch ticking, was removed from the testing environment. Participants were presented with the set of time intervals in a randomised order, and again not less than thirty minutes later. For each interval, the procedure was the same: the experimenter first presented an interval of time by saying “start” as it commenced and “stop” at its end. The experimenter then told the participant to “start” and the participant said “stop” when they felt they had reproduced an interval of similar length. The actual time of the period was recorded.

Results

Figure 10 displays the estimates made by each patient and the control mean performance for each true time, plotted against the true time. The axes on the figure are logarithmic. Estimation by

controls was generally accurate but shows the tendency to underestimate longer intervals reflective of the larger literature (Eisler, 1976). The upper panel shows performance of the four temporal lobe amnesic patients, and the continuum of performance includes those who made relatively few errors, such as PP, to JY who demonstrates more marked errors. Specifically, JY shows a tendency to underestimate later time intervals, together with one large overestimation for the shortest interval. The lower panel shows performance by the two patients with Korsakoff's syndrome, DF and RD, and frontal patients KK and JB. The estimates made by the frontal patients fall fairly close to the control curve, relative to the Korsakoff's patients who show greater errors; in RD's case these are overwhelmingly underestimations but DF shows both under and overestimations.

The raw estimated times recorded were taken and transformed to enable useful analysis. After examining the data, error scores for each trial were derived by finding the difference between true and estimated times, such that an estimate of 4.5 seconds would result in an error score of -1.5 if the true time was 6 seconds, or an error score of 1.5 if the true time was 3 seconds. Following Shaw and Aggleton (1994), errors were transformed into absolute error scores as these are "more sensitive in detecting decrements in timing performance" (p864); this is achieved by forcing the signs of all errors to be positive, preventing under and overestimates from cancelling one another out. At this point the two trials for each time period were averaged together, giving an average magnitude of error for every time period for each patient. An exception was for JY's single overestimation, where his performance over these shorter timescales was normal. Periods of marked slowing are a feature of JY's behavioural profile, which tend to come and go and do not reflect the cognitive trait the test is intending to probe. As a consequence it was decided that this single data point may have been reflective of an instance of slowed behaviour, and so this data point, which may be seen in Figure 10, was excluded, leaving his score for this period (3 seconds) based on a single score.

At this stage, scores provide us with information about the magnitude of error, but not the relative magnitude; an error score of 1 seconds is not substantive for a true time of 48 seconds, but it is for a true time of 3 seconds. As such, absolute errors were transformed into proportionate error scores by dividing them by the true time, such that an error of 1 second yielded a proportional error of .33 for the 3-second interval, but .021 for the 48-second interval.

Finally, the average and spread of control scores for each true time was used to convert all scores into standard scores with a control mean of 0 and S.D. of 1. Patient scores can thus be assessed in terms of their degree of deviation from control performance. Their performance can be

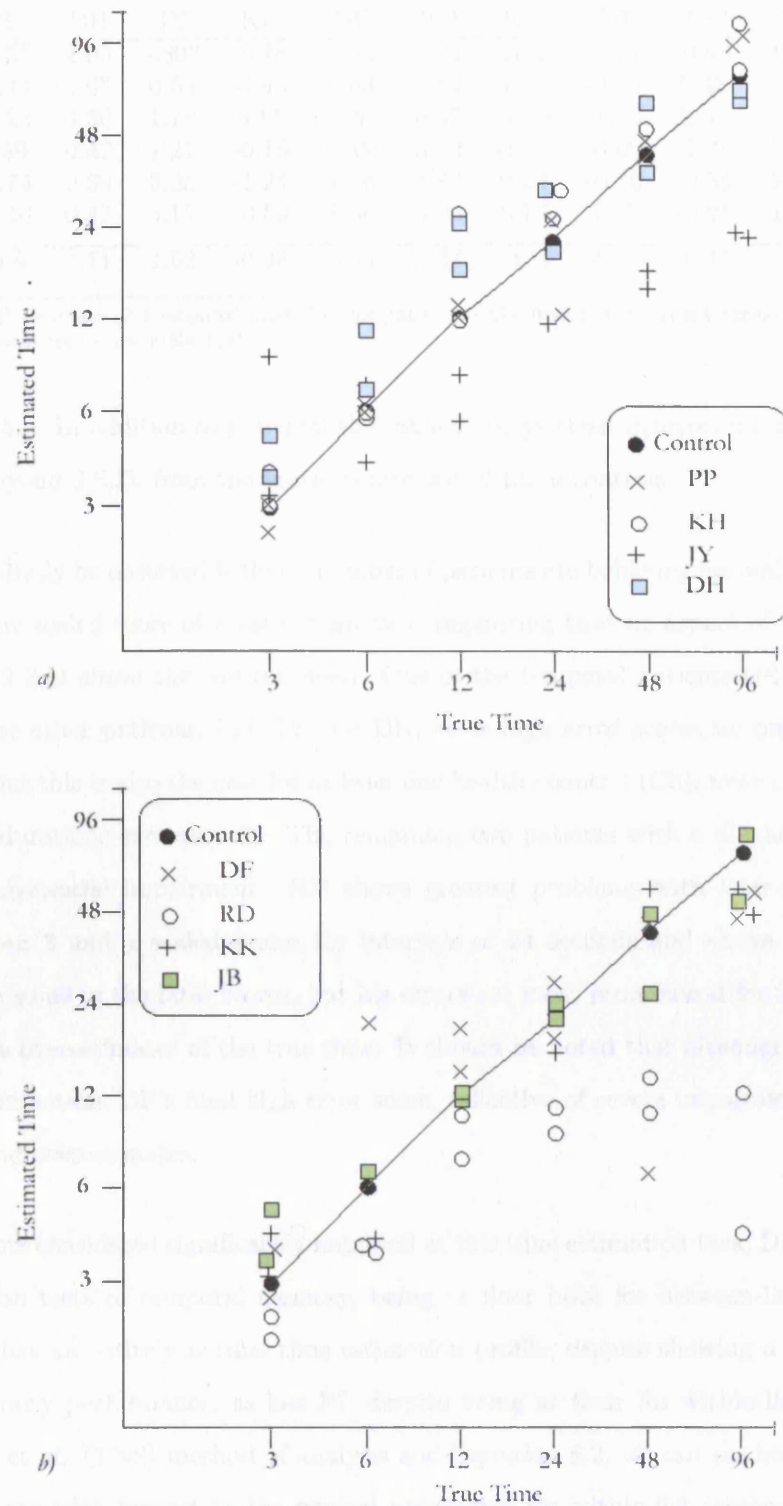


Fig. 5.4: Time intervals reproduced by patients and controls relative to true time of presented intervals. a) Performance of amnesic patients PP, KH, JY, and DH. b) Performance of Korsakoff patients DF and RD, and frontal patients KK and JB. Curves with filled points denote average control performance. When two or more points coincide away from the control curve they are presented slightly horizontally displaced for clarity.

Tab. 5.9: Normalised absolute error scores for time estimation by patients and poor scoring controls.

Interval	PP	DH	JY	KH	DF	RD	KK	JB	Ca	Cb	Cc
3	-0.55	2.03	-0.80 ^a	-0.18	-0.12	0.92	1.91	0.43	-0.43	1.54	2.28
6	-1.44	2.67	0.54	-1.44	9.03	1.44	-0.58	-0.29	0.43	-1.40	1.52
12	-1.23	4.30	1.78	3.11	20.20	0.39	-1.49	-1.46	2.68	1.22	1.09
24	0.59	0.47	1.21	-0.15	-0.05	3.52	-1.37	-0.09	-1.35	1.97	-0.79
48	-0.74	0.30	3.25	-1.24	1.96	3.87	0.23	-0.16	-0.35	2.78	-1.25
96	-1.40	0.47	3.12	-0.59	1.36	4.04	0.16	1.25	-0.26	1.54	-1.13
Mean	-0.8	1.71	1.52	-0.08	5.44	2.37	-0.19	-0.05	-0.12	1.27	0.29

^a The very high estimate (9.1 seconds) made by this patient on the first trial for this interval was removed in calculating this score — see main text

seen in Table 5.9. In addition to patients, the table displays those controls for whom one or more scores were beyond 2 S.D. from the mean, comprised of three controls.

What can firstly be observed is that a number of patients are behaving normally. Neither frontal patient has any scaled score of greater than two, suggesting that no aspect of their performance is more than 2 S.D above the control mean. One of the temporal patients (PP) shows a similar pattern. Three other patients, KH, JY and DH, show high error scores for one or two intervals respectively, but this is also the case for at least one healthy control (Cb); none of their mean error scores across durations exceeds 1.96. The remaining two patients with a diagnosis of Korsakoff's show more substantial impairment. RD shows greatest problems with later intervals, reliably scoring between 3 and 4 scaled scores for intervals of 24 seconds and above. DF shows some difficulty with some of the later scores, but his errors are most pronounced for intervals 6 and 12, giving massive overestimates of the true time. It should be noted that although RD's errors tend toward overestimation, DF's final high error score, reflective of severe impairment is composed of both under and overestimates.

The patients considered significantly impaired at this time estimation task, DF and RD, showed impairments on tests of temporal memory, being at floor both for between-list and within-list. However, JB has an entirely normal time estimation profile, despite showing a similar pattern of temporal memory performance, as has PP despite being at floor for within-list recency. Using the Crawford et al. (1998) method of analysis and Equation 5.2, we can see how abnormal these discrepancies are with respect to the normal population for within-list recency (this is unfortunately not a possible approach with between-list, as JB's chance performance does not generate a sufficiently large score to be considered abnormal, due to wide variation in the control sample's performance). This analysis reveals that a discrepancy of JB's size or greater would only be found

in 1.1% of the population, and PP's discrepancy found only in .73% of the population. It appears that these patients show a reverse pattern to H.M. (Richards, 1973) and are specific instances of the pattern suggested by Shaw and Aggleton (1994, 1995).

What relationship does temporal estimation have to measures of temporal memory? Correlating the standard scores of mean absolute error against the standardised t-values derived for both recency tasks in our patient group, we find no significant relationship to recency errors, neither within-list nor between-list, for either patients or controls, as displayed in Figure 5.10.

Tab. 5.10: Correlations between time estimation and temporal memory measures in patients and in controls

	Patients		Controls	
	Within-recency	Between-recency	Within-recency	Between-recency
Time estimation	.009	-.368	-.126	.143
p-value:	.984	.370	.619	.572

As noted earlier, the patient and control samples differ on several demographic measures, notably age and IQ. In order to assess the degree to which these differences may have impacted the findings, these measures were correlated with timing error and each of the context measures from Experiment 9. Although several experimental measures correlated together, as described above and earlier, age and IQ showed no relationship with any of these variables. IQ constituted an 18-point spread, and age a 36-year spread, which is a reasonable range to detect gross influence. This will be discussed more fully in the general discussion.

Discussion

This experiment sought to investigate whether impairments in time cognition and temporal memory co-occur or are dissociable from one another. It demonstrates that although temporal cognition impairments are found in instances where the ability to order memory items is poor, individuals can be isolated who have very poor recency memory in the face of temporal estimations that are as good or better than controls.

Shaw and Aggleton argue that because temporal duration estimation does not have a strong positive relationship with memory function this counts against theories of temporal estimation, such as that of Michon (1992) wherein duration judgments are dependent on the sequence of events within the duration, and commensurate with models that depend on a clock mechanism. Their

argument proceeds from the premise that the use of a clock, rather than a conscious parsing of events, to produce a sense of elapsed time, frees temporal estimation from dependence on memory, as temporal estimation would rest on a mechanism (action of a pacemaker-accumulator-comparator system) that is independent of memory. What follows from this is that theories of memory which suppose an involvement of a clock mechanism in the workings of memory render this argument inadmissible. Rather, time estimation deficits should co-occur with temporal memory deficits.

On the basis of the single dissociations presented, and the failure to find a relationship between our measures of recency memory and duration estimation, it seems likely that impairments in temporal cognition are not necessary for impairments in temporal memory. This does not preclude the use of time codes in temporal memory judgments, as even a system heavily reliant on temporal information would have other ways in which it could fail; for example, a faulty storage system or inability to retrieve the codes that accompany the memory trace. Discovering a dissociation that fell in the opposite direction, where time estimation was deficient in the face of good recency judgments would provide evidence against this position, suggesting at the very least that other processes may compensate for the lack of access to temporal information, or forcing models to incorporate a dedicated temporal system running independently to that which guides our sense of elapsed time. Nevertheless, this view is most consistent with a position in which memory for the time of an event relies on the successful retrieval of information about the event and its context, rather than being driven by the use of temporal codes derived from the clock-like systems believed to underlie temporal cognition.

General Discussion

The experiments presented in this chapter have involved a case series of patients with a variety of aetiologies to allow the exploration of issues related to temporal memory via neuropsychological methods. They addressed a number of issues. The first of these is the relationship of temporal memory to other forms of context memory. Context memory deficits are an issue for which there are many accounts, and a good deal of equivocal findings. These data suggest that temporal context impairments are commonly found in the presence of one or more other types of context memory deficit. Of the outcomes presented in Table 5.1, JY presents a possible case of outcome 1; however, his performance on within-list recency is poor, and is at floor for some runs. It may suggest that even without access to information that allows inference about item context, under

certain conditions better than chance temporal judgments can be made. Given this patient's poor retention of information (leading to chance performance on a yes/no recognition task after multiple repetition of each item) it may be that this patient exhibits rapid forgetting rates that allow the evaluation of recency based upon the difference in trace strength or generalised strength (Dennis & Humphries, 1998). It is also the case that this may reflect the action of a dedicated temporal memory system; however, it remains to be explained how intrinsic temporal information that assists in making relative judgments of which item was seen more recently would not also assist in a subsequent task to determine whether items have been seen at all, where item markers would present even more disparate temporal codes. PP displays a pattern described in outcome 4, consistent with the Mayes et al. (2004) account where associative recognition may not rely on the same recollective-type properties that underpin more complex contextual associations. In the main, impairments tended to co-occur, and ability for temporal context correlates well with other measures of context memory.

The above is all the case for the within-list measure of recency memory. However, the between-list memory did not appear to correlate well with other context measures, and in one case dissociated entirely from performance for within-list recency (PP). Unfortunately, control performance was both rather worse and more variable for this measure than was expected, making interpretation of scores more difficult than for the other measures. In any case, this dissociation in PP may reflect different processes underpinning the two abilities, or memory impairment transforming the task into a qualitatively different task for the patient, as would be the case if forgetting rates resulted in this task reducing to an old/new recognition task, with earlier items being forgotten and hence not selected. This would be evidence of the artefactual mode of performance I suggested in the introduction to Experiment 9, and may merit further investigation.

Experiment 10 investigated whether interval timing and temporal memory may be intimately related in the way suggested by some researchers (Biebach et al., 1991; G. D. A. Brown & Chater, 2001). Richards (1973) demonstrated that HM's time estimation was extremely impaired, which conflicts with such theories given the suggestion that his temporal memory is preserved (Sagar et al., 1990). A reverse pattern was suggested in Shaw and Aggleton's work with a set of memory impaired patients (1994, 1995), but this had not been presented on an individual case basis. Experiment 10 presented two cases where preserved temporal estimation accompanied impaired temporal context memory, JB and PP. It did not reveal any cases of the reverse pattern, which is more interesting in addressing the timing/memory issue, as it suggests temporal memory does not depend on information from the system responsible for interval timing. The pattern found in JB

and PP suggests instead that intact interval timing is not sufficient to underpin temporal memory. This does not of course imply that such an ability is unnecessary; for example, one could posit that recency memory requires a functioning memory encoding system together with a functioning interval timing system. However, the impairment of performance across aetiology and lesion site suggests that recency memory depends on at least *two* anatomically distinct mechanisms other than timing information. Consequently this finding speaks against a minimal account where all that is necessary is storage of memories together with their associated memory tags, requiring it to specify what roles these two distinct areas must have to allow the processing of this information.

It must be noted that there are limitations to the inferences that can be made from these findings, given that the control and patient samples differ in several ways; most strikingly age, but additionally premorbid IQ, a measure on which only two of eight patients fall above the control mean. The correlations reported at the end of experiment 8 suggest that within the control group, these measures do not reflect level of performance; however, as the patients offer values outside of these ranges this is not a decisive answer.

Some claims are rendered problematic by this. For example, becoming elderly may selectively harm spatial memory. If so, comparisons to an older group will understate the degree of temporal impairment in those patients. If investigations centre on a relative impairment across a patient group: e.g., “Does HIV affect temporal memory more than spatial memory?” then this is problematic, as it will weight one impairment relative to the other.

However, the claims being made in this chapter are not of this type. They rest specifically on relative patterns of performance between patients and measures. Experiment 10 suggests that poor temporal memory does not require poor time estimation, based on the performance of PP and JB. Their performance is clearly impaired at the former task — despite patients with comparable IQ (KH and DH respectively) performing well below cut-off at this task — and normally at the latter, unlike patients RD and DF (with premorbid IQ akin to these critical patients). Notably, both PP and JB, together with those I am comparing at each task, fall on either side of average IQ, in the critical case at 95 and 117 IQ, yet perform similarly. The results of Experiment 9, although lengthier and more qualified, take the same general form: “this memory impairment often, but not always, co-occurs with this impairment”. Similarly, although correlations are not impervious to the compression of one or more measures relative to the others, they will be relatively robust to such alterations. If better performance on one task is roped to better performance in another, the correlation will show this regardless of the scale these measures are transformed to.

Nonetheless, a key extension of this work would be the accumulation of control groups age matched to individual patients, to allow a comprehensive investigation of case by case performance.

In summary, these experiments suggest that temporal context memory may be related to other forms of context memory, and dependent on generalised core memory, rather than a timing signal associated with memories at encoding.

6. GENERAL DISCUSSION

“From a psychological point of view, it seems far more productive to consider the many things that time is in the world and the many ways in which humans experience it. Our environment is rich in temporal structures — in music, in language, in the characteristic durations of familiar events, and in the recurrent cycles of nature and our own activities. To define time as some unitary dimension that cuts across all of these features is to lose sight of the special challenges they pose for perception and cognition. We rely on our ears and specialised regions of the brain to perform the elementary analysis of language and music, but such mechanisms cannot explain our ability to estimate how long the coffee has been perking or to judge the order of past events in our lives” (Friedman, 1990, pg 6–7).

The human experience of time involves phenomena as varied as those offered by Friedman in the passage above, and many more. This thesis has focused on the issue of discerning the temporal context of memories of past occurrences. Some researchers have argued that this ability is underpinned by the same processes that underpin our experience of psychological time, construed as interval timing. Specifically, clock-like structures which allow us to measure the magnitude of durations are employed to mark memories with their chronological status.

I have argued that this approach is a consequence of synecdoche — mistaking the part for the whole. Every cognition and behaviour is dynamic (possesses temporal qualities) as a consequence of our existing in the fourth dimension of time, but necessarily must display different features in different circumstances. This thesis has examined ways in which our memory for daily and enduring experiences could reflect the operation of temporal information derived from clock structures, and counterposed this view with an account where time in memory is solved by peculiarly mnemonic structures. The following sections will deal with these in turn.

6.1 Long term memory

There is a body of evidence which is consistent with the view that ordering sequences in STM is governed by processes that may involve an oscillator system (G. D. A. Brown & Chater, 2001; G. D. A. Brown et al., 2000; N. Burgess & Hitch, 1999; Henson et al., 2003). I have argued that, functionally, there are very particular demands placed upon this ability. Ordering of sequences at short durations is crucial to preserve syntactic properties of speech and motor actions, which are also dependent on the dynamic properties of individual components. There is selective pressure on the recruitment of information from timing systems that simultaneously operate over these periods, in order to satisfy these demands.

However, it seems less clear that such demands arise in LTM. There are no analogues to the syntactic rigidity of speech, and there are no actions extending over minutes whose rate requires great precision. Time is important in deducing the order of related events, in order to infer causality, or monitor the states of relevant entities. As a consequence, I suggested that the ratio-like qualities that are expected to characterise performance when relying on temporal information may not present themselves in long-term order memory judgments. Instead, we may expect other processes more characteristic of general/core memory operation to drive these judgments.

6.1.1 Temporal discrimination and the ratio rule

Chapter 2 demonstrated that our ability to make judgments of recency (JORs) in LTM does not resemble that which a temporal-discrimination theory would predict. Using 20-item lists and JOR pairs separated by 5 positions (and additionally 10 in Experiment 1) yielded a number of outcomes that conflicted with the theory.

- End items (containing targets 16-20) did not outperform other items within the list. This was the case even when single-probe data was taken, where testing immediately follows the end of the list.
- Manipulating test position did not disproportionately affect later study items, despite a disproportionate effect on their temporal ratios.
- Temporal ratios did not correlate with accuracy across items and test positions.

6.1.2 Temporal estimation and judgments of recency

Experiment 10 investigated the extent to which two abilities — duration estimation and judgments of recency — appeared to be related in memory-impaired patients. Previous research suggested that the two abilities show dissociations under certain conditions (Richards, 1973; Shaw & Aggleton, 1994, 1995), which would have consequences for accounts of temporal memory that presume it is underpinned by the same processes as duration estimation. The more interesting pattern of impaired estimation with preserved recency memory — the effect described for patient HM (Richards, 1973) — was not found. This would suggest that the system underpinning our sense of elapsed time is unnecessary for accurate JORs. The pattern of impaired recency memory with preserved estimation suggested by the work of Shaw and Aggleton was found in two patients, one frontal (JB) and one amnesic (PP). This suggests that the ability to accurately judge the duration of elapsed time is not sufficient to produce accurate JORs. This is less consistent with a straightforward timing-code account of temporal memory as it presents two anatomically distinct areas that must be present to support temporal memory in addition to the areas that are responsible for interval timing.

6.1.3 Short-term positional models

The findings of Chapter 2 did not support an extension of the SEM (Henson, 1998b) into LTM. This model is characterised by superior performance for items at both ends of the list, as items are coded with a bi-vector code with respect to those termini. The absence of a recency effect suggests that order representations are not more distinctive at the end of the list, which casts doubt on the operation of such a code. Moreover, Experiment 3 demonstrated that even under conditions where the end of the list was more foreseeable, hence better fulfilling the expectancy demand suggested to be necessary for end-coding, JOR accuracy was not better for the end of the list. This suggests that although this model seems to account well for many characteristics of the serial recall STM data, it is inadequate in describing JORs in LTM.

6.1.4 Temporal landmarks in LTM

The results of Chapters 2 and 3 are consistent with the operation of temporal landmarks that aid order judgments on items that follow them. They suggest, firstly, that items from the beginning of the list are easier to distinguish from other items in a JOR. This effect is independent of

other positional effects such as the study-list lag between items in a JOR, and modality effects, both when the effect is facilitation due to richer representations (picture and enacted item stimuli vs words) and when the effect is impairment due to use of semantically empty stimuli (abstract picture vs words). The effect does not depend on the rehearsability of items (Experiment 4) and does not appear to be reproducible at the end of the list (Experiment 3), or indeed preceding the landmark regardless of its position (Experiment 5). However, an effect with a similar signature of a unidirectional facilitatory effect on immediately following items can be produced at other positions other than the start of the list, as long as the item genuinely confers temporal information (Experiment 5). This suggests that items that follow a landmark may be associated with it, conferring useful temporal information that assist JORs made upon them. This confirms suggestions made by Friedman (2001) that primacy effects may be the consequence of the start of the list acting as a landmark. This thesis was not able to establish the degree to which this mechanism is automatic or the consequence of intentional strategy use (Experiment 6). Automaticity in temporal order tasks has been a topic of continuing investigation (Naveh-Benjamin, 1990; Schmitter-Edgecombe & Simpson, 2001) and the issue of the degree to which landmark use may be intentional is an interesting one.

6.1.5 Modality and association

Modality effects were investigated in Experiments 1 and 4, revealing findings attributable neither to temporal effects nor landmark effects. Experiment 1 demonstrated that JORs are performed more accurately for enacted action sequences and representational pictorial stimuli than for word stimuli; Experiment 4 revealed that word stimuli yielded better performance than for abstract pictorial stimuli. This effect was additive across Start-End effects.

One implication of this was to undermine the possibility that reported superior order judgments for enacted action stimuli (McAndrews & Milner, 1991; Nilsson & Cohen, 1988) was accountable to the recruitment of temporal information by action sequences at durations beyond the STM range. As pictorial stimuli also showed superior performance, and the degree of facilitation was not significantly different between these modalities, the more parsimonious interpretation is that this facilitation is an example of the modality effect (Paivio, Rogers, & Smythe, 1968), due to richer representations for memory items, possibly as a consequence of encoding information via verbal and non-verbal routes.

The data also suggests that the modality effect may reflect a different kind of process at work from the temporal landmark effects discussed above. The difference in performance between actions/pictures and words, and words and abstract pictures, was similar across positions. I have suggested that this could reflect the degree to which stimuli offer themselves to inter-item, or item-environment associations. This does not preclude positional accounts, as the item-environment associations could include coding items against positional placeholders. Verbal labels, especially when they are tied to semantically meaningful representations, such as word nouns, offer an extremely useful resource to tie items together. It enables a variety of strategies, including embedding in a narrative, rhyme, alliteration, or consideration of functional relationship. Such strategies are similarly available for pictorial and enacted stimuli, but assisted by a further route (visual or through physical motion) to be employed.

One issue left unanswered by this thesis is whether such associative strategies are decided preemptively or are the consequence of the items themselves. It would be interesting to see whether such strategies are employed for items that follow a landmark, or are reserved for later items which do not offer a simple method for determining position; either possibility is consistent with the data if it assumed that more associative routes benefit association with a landmark as with another item or context.

6.1.6 Source memory

Another issue addressed by this thesis was the extent to which temporal memory was distinct from other forms of source memory. Source memory is typically considered as distinct from item memory, such as memory for position or memory for pairings, where memory that an item is present is insufficient to solve the task (Johnson et al., 1993). Clearly, time-code theories of temporal memory, among others, treat time as quite distinct from these other forms of context. However, the literature has not provided a clear picture. In Experiment 9, I attempted to investigate this more thoroughly using a case series and a task which tapped memory for temporal context, spatial context, and associative recognition (paired item context), as well as a measure of yes-no recognition. The data do not provide definitive evidence to resolve the issue. They do suggest that temporal context impairments may more typically occur with other forms of context memory deficit. Level of ability for temporal context correlates well with other measures of context memory, but only for within-list judgments; between-list did not relate to other measures and there is some indication that this task could be solved via reliance on the higher forgetting rates apparent in

some memory-impaired patients. Also evident was the fact that temporal memory impairments were not solely found in frontal lobe patients, and were seen across aetiology. The results are consistent with the position taken by Kopelman et al. (1997) that rather than temporal context impairment reflecting frontal damage, they may be the consequence of poor “core” memory, where temporal context represents a particularly difficult (and hence sensitive) inference made via access to accurate memory representations.

6.2 Remote and autobiographical memory

If time-tagged information lies inherent in all memories, and informs each temporal memory judgment to some degree, we would expect superior judgment of the dates of events if they were experienced at that date. This was investigated in Experiment 7, by effectively measuring the ability to date a single set of events when they are historical or directly lived events. The data suggest that for this set of events, living through events does not provide an advantage: that is, reconstruction based on general knowledge and plausibility was as accurate as the strategy employed by individuals who had direct access to the event. I should stress that this is necessarily an outcome of the events, and that events that have not enjoyed a subsequent high public profile — or, in the extreme case, events that are not public at all — would not be dated as well by those who did not experience them, relative to those that did. It nevertheless suggests that experience need not confer a direct advantage to dating, where there exists other means by which to attempt the task.

Moreover, a finding that is open to replication for other events (including less well-known ones) is that participants for whom events are historical are more accurate at dating when they know more about the event, whereas participants who have experienced the event do not show this pattern. This latter finding, for older adults with our set of events, is replicated across Experiments 7 and 8, and is consistent with Burt (1992). It suggests the strategy that these participants choose to use does not depend upon the content knowledge they were probed for.

Instead, Experiment 8 suggests that another factor — the degree of specificity to which an event can be placed within a personal life history — distinguishes accurately and falsely dated events. Participants placed events within one or more boxes on a personal time-line, each denoting what can be considered a “life period” (Conway, 1992); these periods have previously been demonstrated to be involved in decision-making about the dating of public events (N. R. Brown, 1990) but this

experiment has shown a quantitative advantage for events localised within a narrower life period (or one rather than a range). Clearly, this finding resonates with the LTM work described above; a life period, after all, is bounded by transitions whose dates are typically well-known, and can consequently act as a temporal landmark; indeed, Shum (1998) describes these as constituting one of the three types of temporal landmark. Staudinger (1999) argues that cognitive psychology should consider taking the “life perspective” as the unit of psychological enquiry. Investigating the interactions between life periods and accuracy of judgments made upon events that fall within them is a small movement towards that perspective.

It appears that participants may rely on the personal context of public events to determine its date in time, using the temporal information conferred by the life period boundaries to “capture” events within a time period. This is consistent with reconstructive accounts of temporal memory (Friedman, 1993), specifically one where autobiographical information from the life period level may be used preferentially to cues from the event itself, whether this be content, the immediate impact of the event or its consequent memorability.

Finally, these experiments do not speak to the issue of whether some kind of chronological organisation occurs *within* events retained in the autobiographical memory system. The elaboration and revisitation of enduring events likely takes the form of chronological walk-throughs; since experience occurs in a chronological fashion, re-experience is likely to benefit from that perspective, beginning at a point and using activated cues and deliberate insertions to recreate the experience. This provides a unity to remembered events that would be impossible for a fragmented, disordered record, which would offer little in terms of any of the suggested functions of autobiographical memory (Bluck et al., 2005) — social communication is difficult if an experience cannot be recounted, planning for the future is trickier when the thread of events is lost, and the sense of a self with a continuous past depends on a coherent revisitation of that past.

6.3 Conclusion

There are various novel findings outlined in the preceding sections, from systematic evidence for a role of temporal landmarks in LTM to quantitative measures of the contribution of temporal information from life periods to events that can be situated within them. I hope that similarly the review of the temporal memory literature and assessments of plausibility of time-coded memories offer some new perspectives on ongoing issues. However, the overall theme of the work presented

here is not new. The thesis proposes that memory problems are solved via the action of memory processes, with in many cases no dedicated mechanism but a variety of routes by which to solve the problem. I have argued that distance and reconstructive location processes may be at work, which merely reflect the distinction made between familiarity and recollection by various theorists which can be seen as integration of items' perceptual aspects versus retrieval of item-item and item-context associations (Mandler, 1980), or quantitative versus qualitative features of memory (Yonelinas, 2002). The Mandler model is perhaps closest to the position I am suggesting, where JORs may be made via comparison of features of the trace itself to determine which "feels" closer, or else depend upon associations made which include item-item associations, item-context and item-landmark associations, which is a "good trick" that the LTM and autobiographical memory systems may have arrived at quite independent of one another.

Time-coding as a dynamic neural mechanism may well be a building block on which order information ultimately relies, by permitting us to parse events as temporally distinct, and distinguish the immediate past from the ongoing. But to say that the temporal information from this signal is consequently stored and encoded for future access is quite a different claim. This thesis has argued that this claim is not supported by the available evidence, and that rather than seeking the essence of time, *our* time may be better spent unlocking the capabilities of the memory system itself.

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APPENDIX

A. JOR DATA FROM EXPERIMENT 1

The following table displays the accuracy of JORs made upon pairs composed of the stated items. Items are presented in ranked order, beginning with those eliciting poorest performance and proceeding to those which elicited better performance. The first column labels the category of pair: start (contains one of items 1–5)= S, end (contains one of items 16–20) = E, or middle(no terminal item)= M, followed by either long(10 item separation) pair = L, or short(5 item separation) = S.

Tab. A.1: Accuracy for each trial pair across participants ordered from lowest to highest

Pair type	Pair position	Mean accuracy
ES	12–17	75.31%
MS	09–14	76.85%
SS	05–10	78.40%
MS	08–13	80.56%
ES	14–19	80.86%
SS	04–09	81.48%
MS	10–15	81.48%
ES	13–18	82.10%
ES	11–16	82.72%
SS	03–08	83.33%
MS	06–11	83.95%
EL	10–20	84.57%
ES	15–20	84.57%
EL	08–18	85.19%
EL	09–19	85.80%
MS	07–12	86.11%
EL	06–16	87.65%
EL	07–17	88.89%
SL	05–15	89.51%
SL	03–13	90.12%
SL	04–14	90.12%
SS	01–06	91.98%
SS	02–07	93.21%
SL	02–12	94.44%
SL	01–11	95.06%

B. EXPERIMENT 2 TEST PAIR ORDER SETS

In Experiment 2 it is crucial that each JOR target is presented at every test position in order to satisfy the constraints of Equation 2.2. A quasi-random method was adopted to produce ten different pair order sets, C1 to C10, the order of which systematically varied across subjects. These are presented below.

Tab. B.1: JOR Target position in test trial sequence within each pair order set

Set code	Test position									
	1	2	3	4	5	6	7	8	9	10
C1	20	19	18	9	16	7	8	6	10	17
C2	6	20	19	10	17	8	9	7	16	18
C3	7	6	20	16	18	9	10	8	17	19
C4	8	7	6	17	19	10	16	9	18	20
C5	9	8	7	18	20	16	17	10	19	6
C6	10	9	8	19	6	17	18	16	20	7
C7	16	10	9	20	7	18	19	17	6	8
C8	17	16	10	6	8	19	20	18	7	9
C9	18	17	16	7	9	20	6	19	8	10
C10	19	18	17	8	10	6	7	20	9	16

C. SAMPLE PAGES FROM PEKT AND MODIFIED PEKT

PEKT

Berlin Wall torn down

What movement had built the wall?

Liberals

Anarchists

Capitalists

Communists

Which state did this create (or recreate)?

Germany

Ethiopia

Poland

Portugal

On what year did the actual event occur?

1971

1980

1989

1998

modified PEKT

Berlin Wall torn down

What movement had built the wall?

Liberals

Anarchists

Capitalists

Communists

Which state did this create (or recreate)?

Germany

Ethiopia

Poland

Portugal

How striking was this event at the time?

1 2 3 4 5

not at all a little somewhat highly incredibly

How memorable is this event now?

1 2 3 4 5

not at all a little somewhat highly incredibly

On what year did the actual event occur?

1971

1980

1989

1998

D. SUMMARY OF EVENTS AND QUESTIONS FOR PEKT

Berlin Wall torn down.

What movement had built the wall?	Liberals	Anarchists	Capitalists	Communists*
Which state did this create (or recreate)?	Germany*	Ethiopia	Poland	Portugal
What year did it happen?	1971	1980	1989*	1998

A siege of a religious cult at 'Waco' comes to an end.

What was the name of the cult leader?	Stuart Morris	Andrew Mackenzie	Robert Finlay	David Koresh*
How did it end?	The government went away	The cult gave themselves up	Tanks stormed the complex*	All the cult escaped underground
What year did it happen?	1966	1975	1984	1993*

Margaret Thatcher resigns as Prime Minister.

What major issue made her unpopular?	Gay rights	Poll tax*	Military funding	Union strikes
Which of these was not a candidate in the following leadership challenge?	Douglas Hurd	Michael Heseltine	John Major	William Hague*
What year did it happen?	1963	1972	1981	1990*

Clive Sinclair launches the C5 car.

How is this device powered?	Electricity*	Nuclear power	Sugar water	Pedals
What other area is the creator known for?	Road safety	Modern farming	Computer technology*	Aviation
What year did it happen?	1976	1985*	1994	2003

The Beatles disband.

Where were they from?	California	London	Birmingham	Merseyside*
Which of these is not a Beatle?	Paul McCartney	Jim Stevens*	George Harrison	John Lennon
What year did it happen?	1970*	1979	1988	1997

Channel Tunnel opens.

Which countries does this connect?	Germany and Switzerland	Belgium and UK	France and UK*	Wales and Ireland
What can travel on it?	Bicycles	Trains	Cars	Cars and Trains*
What year did it happen?	1977	1986	1995*	2004

IRA bombs Conservative conference at Brighton.

What was bombed?	Grand Hotel*	City Park	Municipal Leisure Centre	Opera House
Which leading Tory was injured in the attack?	Ian Duncan Smith	Michael Portillo	Nigel Lawson	Norman Tebbit*
What year did it happen?	1957	1966	1975	1984*

Elvis Presley dies.

What was the name of his home in Memphis, Tennessee?	Castle Presley	The Old Pad	Gracelands*	Home
What was the cause of death?	Drug overdose*	Car accident	Fell down stairs	Drowning

What year did it happen?	1968	1977*	1986	1995
<i>OJ Simpson put on trial for murder.</i>				
What the result of the trial?	Guilty, on appeal	Guilty	Not guilty*	Still ongoing
Who was he accused of murdering?	His wife*	His agent	His mother	A prostitute
What year did it happen?	1977	1986	1995*	2004
<i>Hostage negotiator John McCarthy released from captivity.</i>				
Where was he captured?	Beirut*	Dubai	Bagdad	Cairo
How long was he imprisoned?	Around 1 year	Around 5 years*	Around 6 months	Around 10 years
What year did it happen?	1973	1982	1991*	2000
<i>Britain joins the EEC.</i>				
What did EEC stand for?	European Eating Comissariat	Ethnic Equality Commission	Easterly Elder Council	European Econ- omic Commu- nity*
Which political party ruled Britain at the time?	Wilson's Labour	Heaths Conserva- tives*	Thatchers Conser- vatives	Churchills Labour
What year did it happen?	1973*	1982	1991	2000
<i>The smash film E.T. gets its UK debut release for Christmas.</i>				
What is the film about?	A robot	A dog	An alien*	A spy
Who directed it?	Martin Scorsese	Rowan Atkinson	Steven Spielberg*	Ron Howard
What year did it happen?	1955	1964	1973	1982*
<i>Lord Lucan disappears.</i>				
Why did he disappear?	He was bored	Suspected of murder*	Gambling debts	Spy
Where did he disappear from?	England*	Yugoslavia	Hawaii	America
What year did it happen?	1974*	1985	1994	2003
<i>Chairman Mao dies.</i>				
What country did he rule?	China*	Vietnam	Indonesia	North Korea
What is the name given to his circle of advisors?	State Action Unit	Gang of Four*	Iron Wing	People For Change
What year did it happen?	1976*	1985	1994	2003
<i>Strikes in UK leads to 'Winter of Discontent'.</i>				
Why were there strikes?	A big tax increase for the rich	Government would not guarantee hu- man rights	Protest against war	Cuts in workers wages*
Who did this eventually unseat from power?	Jim Callaghan's Labour govern- ment*	Neal Kinnock's Labour Govern- ment	Margaret Thatcher's government Tory	David Steel's Lib- eral government
What year did it happen?	1961	1970	1979*	1988
<i>Pope John Paul II inaugurated.</i>				
What was striking about this event?	He had announced he was not inter- ested in popehood	His predecessor died a month after election*	It caused a split in the catholic church	It was the first time the post had a salary attached
Where did this occur?	Genoa	Venice	Vatican*	Venezuela
What year did it happen?	1978*	1987	1996	2003
<i>Football fans crushed to death in 'Hillsborough' disaster.</i>				
Which football team did these fans support?	Southampton	Arsenal	Liverpool*	Manchester United
How many people were killed?	96*	8	20	420
What year did it happen?	1979	1988*	1997	2003
<i>Mike Tyson is given a 6-year jail sentence.</i>				
What was his profession?	Bank Manager	Lawyer	Boxer*	American football player
What was his crime?	Speeding	Armed Robbery	Rape*	Murder

What year did it happen?	1973	1982	1991*	2000
<i>Murderer Charles Manson is sentenced to death.</i>				
Who was he known to have killed?	Singer Joni Mitchell	Mime Marcel Marceau	Actress Sharon Tate*	Director Francis Ford Coppola
Where did it occur?	New York USA	Toronto Canada	California USA*	Mexico City Mexico
What year did it happen?	1971*	1980	1989	1998
<i>The Live Aid charity concert is held.</i>				
What was this in aid of?	Cancer research	Violence on American streets	NHS	
Famine in Ethiopia*				
What was the famous single connected to this?	Suspicious Minds	Heard It on The Grapevine	Like A Virgin	Do they Know It's Christmas?*
What year did it happen?	1976	1985*	1994	2003
<i>Ronald Reagan becomes President.</i>				
What was his old profession?	Actor*	Taxi Driver	Policeman	Accountant
What was seen to be his major characteristic?	Very feminine	Multilingual	Rather stupid*	Very intelligent
What year did it happen?	1972	1981*	1990	1999
<i>Princess Diana dies.</i>				
How did she die?	Car accident*	Drugs overdose	Suicide by hanging	Cancer
Where did it occur?	New York	Paris*	London	Sydney
What year did it happen?	1970	1979	1988	1997*
<i>Eric Morecambe dies.</i>				
Who was his comedic partner?	Peter Sellers	Arnold Wiseman	Bobby Ball	Ernie Wise*
How did he die?	Drowning	Car accident	Murdered	Heart attack*
What year did it happen?	1975	1984*	1993	2002
<i>Unionists and Republicans sign up to the 'Good Friday' agreement in Northern Ireland.</i>				
What organisation is associated with this situation?	CND	IRA*	GRE	TUC
Who is a leading Republican?	Toby McGinty	Gerry Adams*	Alan White	Robert Adams
What year did it happen?	1978	1989	1998*	2003
<i>Euro Disney opens.</i>				
Where is this based?	Antwerp	Paris*	Munich	Swansea
Why did some French resist the park?	It was a dumping down - a 'cultural chernobyl'*	Talking mice were seen as unreasonable 'madness of the mouse'	It wasn't big enough for the French demand - 'malaise petit'	It was seen as antirevolutionary - 'Disney bourgeoisie'
What year did it happen?	1965	1974	1983	1992*
<i>John Lennon is shot dead.</i>				
Who was his assassin?	A wronged lover	A professional hit-man	An obsessed fan*	A rival musician
What book is said to have inspired this killing?	The Wizard of Oz	Great Expectations	The 3 musketeers	Catcher in the Rye*
What year did it happen?	1971	1980*	1989	1998
<i>Watergate Scandal occurs.</i>				
Which president was involved in this?	Nixon*	Reagan	Lincoln	Clinton
What was one of the activities involved?	Unethical stock selling	Bugging rival political offices*	Abuse of workers rights	Sexual misconduct
What year did it happen?	1974*	1983	1992	2001
<i>Melt down of nuclear reactor at Chernobyl.</i>				
Where did this occur?	Turkey	Former USSR*	Southern China	Jordan
Who was the president of the country at the time?	Indira Gandhi	Mikhail Gorbachev*	Mao Tse Tung	Imrad Kobola
What year did it happen?	1968	1977	1986*	1995

The Dunblane massacre occurs in Scotland.

What was attacked in this event?	Block of flats	Hospital	Church	School*
What was used to do this?	Knives	Kerosene	Gas	Firearms*
What year did it happen?	1969	1978	1987	1996*

The Falklands War occurs.

Who did Britain go to war with over the Falklands Islands?	France	Argentina*	Russia	Brazil
Who was prime minister during the Falklands war?	Tony Blair	Margaret Thatcher*	Harold Wilson	John Major
What year did it happen?	1973	1982*	1991	2000

E. DEFINITIONS OF STANDARD NEUROPSYCHOLOGICAL TESTS

All quotations are taken from Hodges' *Cognitive Assessment for Clinicians* (1999).

Tests of intelligence.

National Adult Reading Test or NART (Nelson, 1985). This task is used to produce an estimate of premorbid IQ, it is built upon the assumption that reading is a highly overlearned skill, a manifestation of crystallised intelligence that is well maintained even in the presence of intellectual impairment. The test is composed of 50 words of irregular spelling, each of which must be read aloud in its correct pronunciation. The number of errors is used to produce the predicted IQ.

Vocabulary (WAIS-III) (Wechsler, 1997). This is a subtest of the WAIS-III which is used as a measure of current verbal intelligence. It consists of 35 words that the subject is asked to define; the words vary from the very common e.g. "bird" up to infrequent words such as "ominous". Subjects are awarded scores for full or partial meaning, and may be prompted if their response suggests they may have a fuller description than the one given (as indicated by the scoring guidelines).

Advanced progressive matrices (Set 1) (Court & Raven, 1986). This test is a non-verbal measure of general intellectual ability, and is a shortened variant of Ravens progressive matrices. The task consists of a number of problem solving tests that must be approached by filling in the missing part of a pattern or design with one of eight possible pieces. This version consists of 12 different tasks, which range in conceptual complexity from simple pattern matching to the application of logical rules. The entire test is always completed regardless of performance.

Tests of executive function.

Verbal fluency (Benton & Hamsher, 1976). Verbal fluency "is a very useful bedside test which is sensitive to frontal 'executive' dysfunction and subtle degrees of semantic memory impairment" (pg 219). The measure used here was the common FAS test of letter fluency. In this

task subjects are given one minute to produce as many words as they can that begin with a given letter of the alphabet: this is conducted three times, with the letters F, A and S used as the target letter. Subjects are told beforehand that proper nouns and the production of repeated variants of a common root (adding different suffixes to a single word) are unacceptable. The scores for correct responses are summed across the three trials.

Cognitive Estimates Test (Shallice & Evans, 1978). This test is sensitive to frontally related impairments in judgment. Subjects are asked to make estimates on questions that require a degree of lateral thinking and novel reasoning, and responses are scored for their unusualness (degree to which the response is found in the normal population). Answers in the correct range score 0.

Trail Making Test (from the Halstead-Reitan Test Battery, Reitan, 1971). This test is commonly used to ascertain difficulty in response inhibition and set-shifting, which are tasks that are seen to have some frontal involvement. It consists of two parts, both of which consist of joining together twenty-five circles spread across the page according to a sequential rule. In part A the circles contain the numbers 1 to 25, and the rule is a simple numerical order rule (join one to two, then two to three etc). In Part B the circles contain the numbers 1 to 13 and the letters A to L: in this part the rule requires the subject to alternate between numbers and letters, both in ascending sequence. In both parts the investigator is required to correct errors made in trail making by the subject. The dependent measure is the time taken to complete each part.

Brixton test (P. W. Burgess & Shallice, 1997). This task investigates the ability to use rules effectively in an abstract visuo-spatial task. Subjects presented with a visual array of ten positions one of which is coloured. They are asked to anticipate the pattern that a coloured feature will take from position to position, given that it will follow certain rules for a time but may then shift to a different one. It thus taps patients ability to shift set and follow rules without perseverating, as well as working memory demands.

Tests of memory.

Digit Span (WMS-III) (Wechsler, 1997). This test taps memory for short series of items. It is composed of two parts: in the digit forwards part, "subjects are asked to repeat back progressively lengthening strings of digits in the same order as they are given by the examiner". The digits are presented at one per second, and perfect recall is required to score. Following

this the digit backwards part is presented, which requires the subject to repeat back the digits in reverse order.

Logical Memory (Wechsler Memory Scale — Revised) (Wechsler, 1984) . This task investigates prose recall ability at both immediate recall and following a half-hour delay. It requires subjects to listen to a short story and reproduce from it as much information as they are able, including names, amounts and other details. Another story is then presented and recalled, and after a half-hour delay subjects must relate as much information as they can recall from each story.

Camden Recognition Memory Tasks (Warrington, 1996). Two of these tasks, face recognition and single word recognition, were employed in this chapter. The Camden presents thirty items consecutively, with the subject asked to make verbal responses as to whether the stimulus is pleasant or unpleasant in order to ensure a common level of encoding. Subjects subsequently are asked to make thirty forced-choice recognition decisions between a pair of items, one a target seen in the previous list, the other an unseen foil.

In some instances it was not possible to conduct these exact tasks and the following equivalents were used instead.

Modified Wisconsin Card Sorting Task (Nelson, 1976). This task involves the presentation of a series of cards presenting a set of items which vary by quantity, shape and colour. Subjects must match these cards against key cards using one rule at a time (e.g., shape), and then be able to desist from using this rule and sorting subsequent cards according to another rule (e.g., colour), continuing until all cards have been sorted. This task measures rule compliance, set shifting and perseveration in a similar manner to the Brixton task.

Warrington Recognition Memory Task (Warrington, 1984). The Warrington is similar to the Camden but involves fifty rather than thirty trials.

F. SETS OF STUDY PAIRS, DISTRACTERS AND TEST PAIRS FROM
TSARC

Session A List 1		Session A List 2	
radio	pole	trolley	nest
goblet	refrigerator	eagle	skyscraper
monk	carpet	pebble	rake
crowd	passport	guard	earth
violin	airship	ferry	sandal
magician	honeycomb	veil	river
tent	ink	ribbon	triangle
crumb	muzzle	rug	puppy
snow	web	flea	alligator
wig	jelly	broom	sand
gymnastics	crane	ox	forest
girl	mule	towel	bomb
storm	chicken	ivy	harp
alley	scorpion	lemon	doctor
pendulum	world	ticket	wood
elephant	tire	canary	thorn
hotel	walrus	branch	cottage
whistle	plate	volcano	potato
Session B List 1		Session B List 2	
orange	tray	saucer	hurricane
ambulance	wreck	skull	head
albatross	owl	biscuit	mast
queen	ice	napkin	beaver
oyster	barn	bone	ear
tomato	hospital	spider	dagger
foal	weapon	knee	lettuce
sail	mirror	horn	jeep
pyramid	garden	path	hoof
sheep	plank	weed	whale
bubble	fang	band	armour
pliers	leg	wand	lobster
screwdriver	lily	tree	witch
watch	tiger	face	sugar
choir	mud	manure	badge
wallet	dummy	leaf	engine
tooth	garlic	salad	juggler
satchel	sponge	tomb	toga

Session A List 1 Distracters		Session A List 2 Distracters	
slipper	shed	submarine	spade
tortoise	limousine	leek	deer
vine	emerald	gravel	man
pill	trombone	dress	shark
needle	ivory	pea	doughnut
magazine	mermaid	hare	teeth
pond	urn	stool	cotton
diamond	marble	beetle	maze
rainbow	pipe	temple	flute
hose	saddle	continent	gallows
gate	gerbil	shower	necklace
stew	oatmeal	cabbage	rat
dancer	desk	fan	helmet
camel	alien	flood	hammer
oven	toaster	valley	shield
apple	coal	statue	hood
wheel	island	gorilla	raspberry
worm	toy	detective	lantern
Session B List 1 Distracters		Session B List 2 Distracters	
egg	fountain	chestnut	ocean
devil	shoe	shawl	pie
king	vase	insect	galaxy
flask	knitting	doll	prairie
rope	swamp	beehive	vinegar
robin	gondola	snail	soap
fox	revolver	hill	lawn
piano	wolf	avalanche	banner
puddle	jacket	ring	sack
claw	prison	uncle	toilet
string	well	stocking	palace
pencil	cube	giant	cliff
jar	comet	stag	missile
tractor	nose	moss	hook
hairpin	zoo	poster	pig
snake	policeman	accordion	clover
uniform	hatchet	foam	dart
cave	basket	twig	whip

Session A List 1 Temporal		Session A List 2 Temporal		
pole	tent*	nest	ribbon*	
snow	mule*	flea	bomb*	
pendulum*	girl	ticket*	towel	
honeycomb	web*	river	alligator*	
hotel*	gymnastics	branch*	ox	
crane*	airship	forest*	sandal	
whistle*	muzzle	volcano*	puppy	
crowd	alley*	guard	lemon*	
tire*	wig	thorn*	broom	
passport	jelly*	earth	sand*	
refrigerator	crumb*	skyscraper	rug*	
chicken*	monk	harp*	pebble	
Session A List 1 Spatial		Session A List 2 Spatial		
crowd*	passport	guard*	earth	
elephant*	tire	canary*	thorn	
refrigerator	goblet*	skyscraper	eagle*	
plate	whistle*	potato	volcano*	
storm*	chicken	ivy*	harp	
muzzle	crumb*	puppy	rug*	
world	pendulum*	wood	ticket*	
web	snow*	alligator	flea*	
magician*	honeycomb	veil*	river	
airship	violin*	sandal	ferry*	
gymnastics*	crane	ox*	forest	
radio*	pole	trolley*	nest	
Session A List 1 AsRecog		Session A List 2 AsRecog		
ink	world	triangle	wood	N
monk	carpet	pebble	rake	Y
walrus	magician	cottage	veil	N
scorpion	alley	doctor	lemon	Y
violin	radio	ferry	trolley	N
wig	jelly	broom	sand	Y
hotel	walrus	branch	cottage	Y
mule	girl	bomb	towel	Y
storm	carpet	ivy	rake	N
ink	tent	triangle	ribbon	Y
goblet	elephant	eagle	canary	N
plate	scorpion	potato	doctor	N

Session A List 1 Temporal		Session A List 2 Temporal		
tray	foal*	hurricane	knee*	
pyramid	leg*	path	lobster*	
choir*	pliers	manure*	wand	
hospital	garden*	dagger	hoof*	
tooth	bubble*	salad	band*	
fang*	barn	armour*	ear	
satchel*	mirror	tomb*	jeep	
queen*	watch	napkin*	face	
dummy	sheep*	engine	weed*	
ice*	plank	beaver*	whale	
wreck*	sail	head*	horn	
lily	albatross*	witch	biscuit*	
Session A List 1 Spatial		Session A List 2 Spatial		
queen	ice*	napkin	beaver*	
wallet*	dummy	leaf*	engine	
wreck	ambulance*	head	skull*	
sponge	satchel*	toga	tomb*	
screwdriver	lily*	tree	witch*	
mirror*	sail	jeep*	horn	
mud*	choir	badge*	manure	
garden*	pyramid	hoof*	path	
tomato	hospital*	spider	dagger*	
barn*	oyster	ear*	bone	
bubble*	fang	band*	armour	
orange	tray*	saucer	hurricane*	
Session A List 1 AsRecog		Session A List 2 AsRecog		
weapon	mud	lettuce	badge	Y
albatross	owl	biscuit	mast	N
garlic	tomato	juggler	spider	N
tiger	watch	sugar	face	Y
oyster	orange	bone	saucer	Y
sheep	plank	weed	whale	Y
tooth	garlic	salad	juggler	Y
leg	pliers	lobster	wand	N
screwdriver	owl	tree	mast	N
weapon	foal	lettuce	knee	N
ambulance	wallet	skull	leaf	N
sponge	tiger	toga	sugar	Y